AD-A132 676 EUROPEAN SCIENTIFIC NOTES VOLUME 37 NUMBER 7(U) OFFICE 1/1
OF NAVAL RESEARCH LONDON (ENGLAND) D MOSHER ET AL.
31 JUL 83 ESN-37-7

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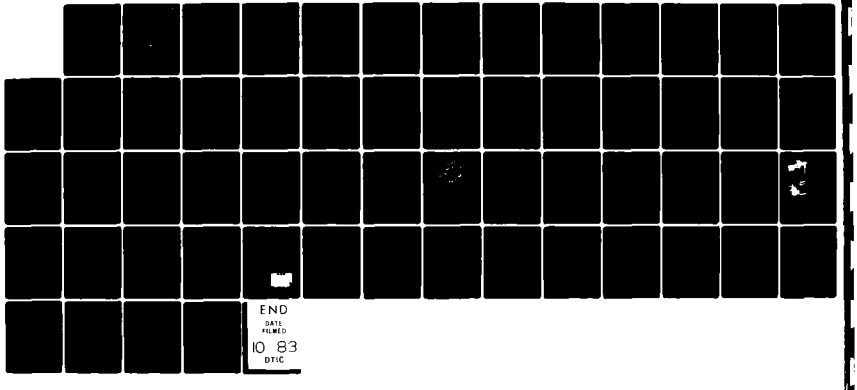

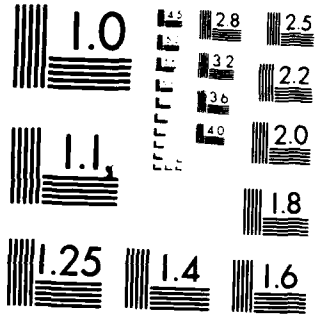

OFFICE OF NAVAL RESEARCH
LONDON

EUROPEAN SCIENTIFIC NOTES

ESN 37-7

31 JULY 1983

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SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER 37-7	2. GOVT ACCESSION NO. AD-A132	3. RECIPIENT'S CATALOG NUMBER 676
4. TITLE (and Subtitle) EUROPEAN SCIENTIFIC NOTES		5. TYPE OF REPORT & PERIOD COVERED Monthly July
		6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) David Mosher and Larry E. Shaffer, editors		8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS US Office of Naval Research Branch Office London Box 39 FPO NY 09510		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
11. CONTROLLING OFFICE NAME AND ADDRESS		12. REPORT DATE 31 July 1983
		13. NUMBER OF PAGES
14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office)		15. SECURITY CLASS. (of this report) UNCLASSIFIED
		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

APPROVED FOR PUBLIC RELEASE: DISTRIBUTION UNLIMITED

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

European Scientific Notes (ESN) is a monthly publication with brief articles on recent developments in European scientific research. The publication is not intended to be part of the scientific literature. The value of ESN articles to Americans is to call attention to current developments in European Science and technology and to the institutions and people responsible for these efforts. ESN authors are primarily ONRL staff members. Occasionally articles are prepared by or in cooperation with staff members of the USAF

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S/N 0102-LF-014-6601

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EUROPEAN SCIENTIFIC NOTES
OFFICE OF NAVAL RESEARCH
LONDON

Edited by David Mosher
Larry E. Shaffer

Vol 37, No. 7 31 July 1983

BEHAVIORAL SCIENCES

BIOLOGICAL SCIENCES

COMPUTER SCIENCES

ELECTRONICS

The properties of optical fibers are altered by many different changes in the environment. As sensors of magnetic fields, temperature, and rotation, optical fibers may surpass any other device.

MATERIAL SCIENCES

This is the fourth in a series of articles reporting research on fiber composite materials in the UK. Research at the National Physical Laboratory and the Univ. of Liverpool is highlighted this month.

The joint US-UK International Nickel Company Mechanically Alloyed Products (INCO MAP) organization arranged this second conference on the strength, thermal stability, and corrosion properties of the oxide dispersion strengthened superalloys: MA754, 956, and 6000. The alloys, developed for advanced military aircraft turbine engine components, are now finding their way into industrial gas turbines and are candidate materials for nuclear power and petrochemical plant uses.

OCEAN SCIENCES

The meeting focused on remote sensing of shelf seas hydrodynamics and pollution transport.

OPERATIONS RESEARCH

Operations research at the Univ. of Birmingham is part of their "engineering production" activity; it involves close interaction with industry.

PHYSICS

This is the first of two articles on static electrification research at the Univ. of Manchester Institute of Science and Technology. Investigations of contact electrification of insulators by metals are described. The phenomenon is responsible for damage of semiconductor electronic components during manufacture. A discussion of static charging by collisions of aircraft with ice particles will appear in a future article.

ESN 37-7 (1983)

European Scientific Notes is a Class I Periodical prepared and distributed by the Office of Naval Research, London, in accordance with NAVEXOS-P-35.

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BEHAVIORAL SCIENCES

DECISIONS IN SUBMARINE ESCAPE AND RESCUE

Grave choices must be made when a submarine becomes severely disabled. Until recently, escape was about the only way for a crew to survive, and much effort has gone into the development of good escape suits and escape compartment design. Escape is feasible only in moderate water depths; below 200 m, decompression sickness and bends become probable and serious. In fact, escape has been demonstrated only to about 180 m. Even if everything works and a man lives through the trauma of the escape pressure profile and reaches the surface, survival on the open sea would still be difficult. To help attract the attention of rescue crews, modern escape systems have marker buoys as part of the survival package.

About 10 years ago, intensive work on a deep submergence rescue vehicle (DSRV) was done in several countries, principally the US, the UK, and Sweden. The basic idea was to build a small, special vehicle that could be transported by military airlift to any place in the world, could be controlled from a second nearby submarine so that the DSRV could seal itself to a stricken vessel, and could repeatedly evacuate personnel at relatively high pressures. Obviously the feasibility of any particular DSRV rescue would depend on conditions inside the disabled boat, as even under the best circumstances it would take hours to deliver a DSRV, control it so that it could seal itself to the disabled boat, and carry out a complex rescue operation. Men trapped in a submarine compartment where pressure is rising uncontrollably could not wait very long. But if life-support conditions in the affected boat could be maintained for some hours, a rescue operation at a depth of about 400 m might be attempted. And the psychological effect of having some *possibility* of rescue at extreme depths would be positive for the entire submarine community.

At a recent international symposium held by the Royal Institution of Naval Architects (London, 17 through 20 May 1983), D. Wilson of the UK Ministry of Defence presented a thorough analysis of the status of research on escape and rescue. Though his presentation was unofficial, it probably represented the thinking of many European authorities on the subject. It also showed that an escape and rescue "decision tree" can be formulated, at least for some conditions.

There have been few submarine sinkings in peacetime; since 1950, some 16 losses have been reasonably well documented in western naval literature. Four of the losses were believed to be due to collisions, two to explosions, and three to either hull or systems failures. According to Wilson's summary, about one-half of the losses occurred in deep water (>600 m), where no escape or rescue was feasible with methods existing at the time.

Research with animals, supplemented with limited human data, allows one to draw some prediction curves for feasible submarine escapes. For example, Figure 1 shows Wilson's curve of pre-exposure pressure and escape depth. If the curve is correct, then a safe-to-escape domain is shown by the area to the left of the dashed line; outside this area, bends and other decompression involvements become more likely. Escape prediction curves of this type could become slightly more favorable with the provision of decompression stops, with controllable ascent rates, or with better oxygen-mixture systems. But the gains from such improvements are marginal; it will be some time before escape from extreme depths is possible.

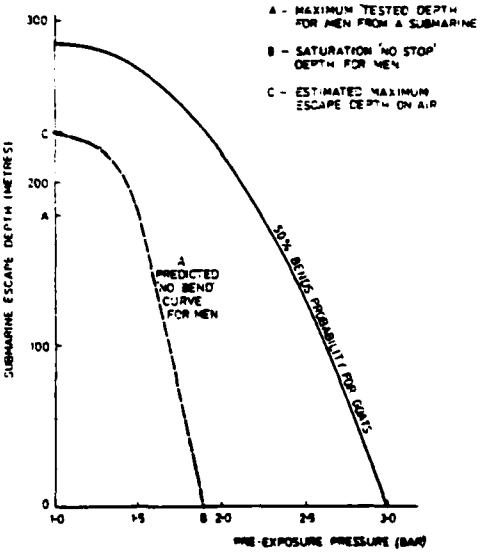

Figure 1. Relationship between pre-exposure pressure, depth, 50% bends curve for goats and predicted "no-bend" curve for men (adapted from Wilson, 1983).

Table 1

Advantages and Disadvantges of Escape and Rescue (Adapted from Wilson, 1983)

	ESCAPE			RESCUE		
Factor	Effect	Plus +	Minus -	Effect	Plus +	Minus -
Time	Escape can be made at any time according to circumstances.	/(A)		DSRV arrival will take considerable time and is dependent on a long chain of events.		
Exposure	Exposure to escape profile pressures, and sea water and weather can radically reduce survival probability.		/	No problems.	/(B)	
Decompression Sickness	Pulmonary barotrauma and bends are probable, and increase with escape depth.		/	Can be conducted at pressure in DISSUB of 1 - 3.3 bars.	/(B)	
DISSUB Environment	Available when atmosphere or pressure becomes untenable.	/		Can be conducted at pressure in DISSUB of 1 - 3.3 bar.	/	
Evacuation Rate	Quickest evacuation from DISSUB possible.	/		Slow evacuation, dependent on DSRV round trip time.		/
Depth	Only proven to 180 metres.		/	Can be mounted at NCD of submarine, provided hull pressure tight.	/	
Psychology	Regular training makes escapees confident of system, but survival after escape an unknown.		/	Waiting time may reduce morale of survivors but knowledge that once DSRV has arrived, survival is near certain, is important.		/
Simplicity	Simple	/		Dependent on complex mix of human and material factors outside DISSUB control.		/
Autonomy	Under direct control of senior survivor	/		Outside control of DISSUB		/
Familiarity	Familiar through regular training.	/		Unfamiliar - but no training required by survivors.	/	
Sea Conditions	Not affected by poor visibility	/		Strong currents and poor visibility could inhibit rescue.		/
Cost	Little maintenance	/		Regular training of pilots an exercising of system required. Regular maintenance needed.		/

(A) The overriding reason for retaining an escape facility.

(B) Prime considerations for retaining a rescue capability as the preferred method, when time is not a factor.

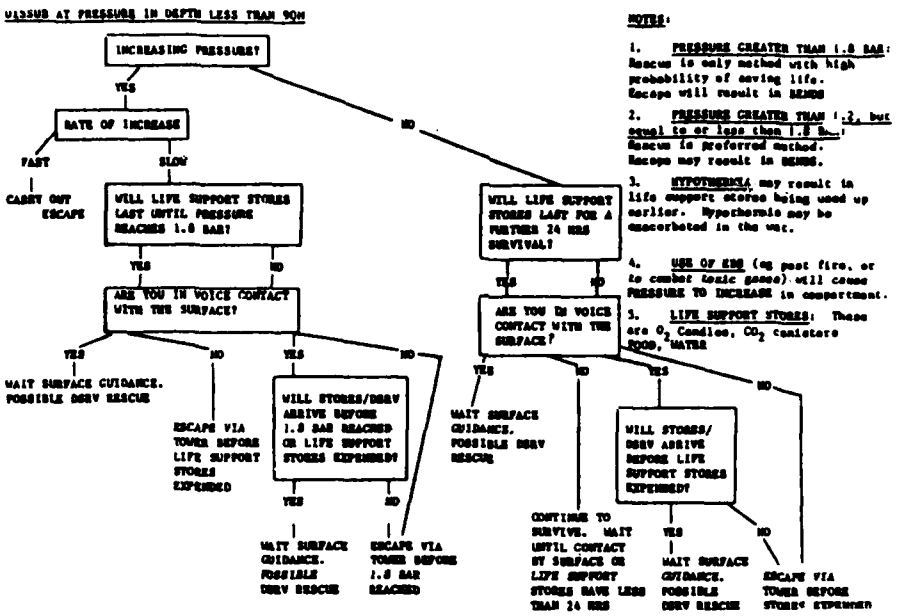

Figure 2. Escape and rescue decision tree for a submarine at moderate depth (adapted from Wilson, 1983).

"Life support" conditions aboard a disabled craft are critical--especially if a DSRV is the only method of survival. Navy medical research around the world now has led to improved CO_2 absorbers, special pumps, and batteries for the escape compartment; there is even a manual foot pump device for driving air through the absorbing canisters.

The US Navy concept of an air-delivered DSRV was tested in an exercise with the UK Royal Navy in 1979. The vehicle was flown by the US Air Force from California to Glasgow, and was then trucked to the Clyde Submarine Base in Scotland, where it was attached to a Royal Navy SSBN nuclear submarine. The fitted submarine then proceeded to a rescue trial with the Royal Navy submarine *Odin*, which, for purposes of the exercise, was resting on the bottom in 120 m of water near the Arran Islands. Forty-seven hours after the "flash" summons, the DSRV was connected to the "disabled" boat.

The DSRV carried out seven dives in less than a week and proved that personnel could be rescued safely at moderate depths, provided that many hours were available. There were five dives in which sealed mating was planned, and four of these were completed in ways that permitted personnel transfer. Three or four hours were necessary for each cycle: lift off from SSBN, transit to "disabled" ship, sonar contact, seal and transfer rescue load, and return to SSBN. On the same trial, a commercial unmanned submersible was operated in a support role with the DSRV and proved that it could deliver materials to the stricken boat in a special pod. The auxiliary delivery role might well be critical in some situations; for example, life support materials might be provided until the DSRV rescue activities can begin. Western navies are therefore vitally interested in commercial unmanned submersibles that can play the support role, and work goes forward on these craft. There are major problems of sealing, visibility, and control that are common to commercial submersibles and naval submarines.

Not all European trials with rescue submersibles have been so encouraging. In 1981, the Royal Navy attempted a dry transfer with two submergence vehicles, the Perry Oceanics PC1801 and the Slingsby LR5. Though hard seal was eventually achieved, there were problems with controlling the thrusters, with communications between the "disabled" ship and the vehicle control ship, and with precise visual locating of the rescue vehicle. Some of the control and display problems during approach are well defined and could be studied in simulators. (For a more detailed description of the trial, see ONRL MAS Bulletin 1-82, 1982.)

Wilson's table of the escape and rescue alternatives summarizes what can be done right now. The dozen factors in Table 1 probably cover the problem as well as any unclassified source.

When a submarine is disabled, the

crew might benefit from a definite survival strategy that reflects local conditions and options. In Figure 2, Wilson shows a decision tree that might apply to men trapped at a moderate depth. Such decision aids must, of course, receive the most intensive examination before a navy uses them. But they do indicate the probabilities and other data needed for a decision analysis in such circumstances; they may also help training managers. Thus, two trends are encouraging: (1) hardware and control capabilities in all branches of submarine escape and rescue are becoming more effective, (2) at the same time, decision logic concerning alternatives can be improved so that as many people as possible survive.

Reference

Wilson, D., "Submarine Escape and Rescue. A Review of Recent Developments in the Royal Navy," in *Naval Submarines: Vol II, Papers 10-14, RINA International Symposium* (The Royal Institution of Naval Architects, 1983).

N.A. Bond, Jr.

BIOLOGICAL SCIENCES

BIOTECH 83

The 1st World Conference and Exhibition on the Commercial Applications and Implications of Biotechnology was held in London, England, from 4 through 6 May 1983. The conference was organized along three concurrent streams, the Climate for Biotechnology, Enabling Technologies, and Technological Advances. There were 73 lectures presented in 14 panel sessions, 30 poster presentations, and 76 industrial exhibits. There were over 900 delegates representing 33 nations.

The Climate for Biotechnology stream considered national and international strategies that may affect business planning and marketing. The Enabling Technologies stream highlighted advances in the design of production plants using biological systems. Fermentation systems, tissue culture, monoclonal antibodies, genetic engineering in agriculture, and the use of microbes to enhance oil recovery were discussed. The Technological Advances stream considered novel biocatalyst systems, biosensors, and bioelectronic devices.

Climate for Biotechnology

The national investment in biotechnology research will be high in western European nations, Japan, China, and the US. It is important to identify technologies upon which future research will depend. Industry is most likely to identify markets, products, and processes and is expected to gather the economic resources needed. Government can foster linkages between universities and industry, fund the training of scientists having expertise in the new science, develop methods of supporting the interactions, and assume support of high-risk projects in both basic and applied research. Fermentations, chemical conversions, materials production, mining-oil recovery, and food processing are areas offering opportunities to the biotechnologist.

The views presented by Masami Tanaka (Ministry for International Trade and Industry [MITI], Japan) were similar to those voiced by representatives of several other national governments. His first point was that universities play an important role in the education of scientists and the pursuit of academic research. The purpose of MITI is to increase the technical capabilities that contribute to the future promotion of bioindustry in Japan. One way to achieve this goal is to promote university-industry linkages by providing governmental funds for large-scale, high risk research programs (i.e., programs in which the potential for economic gain is low during the next 3 to 5 years).

Tanaka stressed the need to increase the level of research activity in the private sector. MITI hopes to do this by financing the construction of institutes, developing software for data processing, and subsidizing the purchase of state-of-the-art research equipment. Tanaka also said that the eight national institutes associated with MITI should interact with industry and support collaborative research projects that are not yet ready for industrial development. Support should consist of training young researchers and making facilities in the national research institutes more accessible to the private sector.

Almost all the national agency representatives agreed that: (1) productive interactions between universities and industry should be increased, and (2) biotechnological approaches should be used only if they result in lower production costs or in a chemical product that is purer than those made by more conventional methods (e.g., from petroleum by-products). Cost is affected by plant size, energy requirements,

price of materials, and ratio of labor to unit products generated. Biotechnology is promising when such factors are considered, according to Ruxton Villet (Elf Aquitane, France) and Ernest Jaworski (Monsanto, US). They agreed that inducements should be provided at a national level to improve contacts between the basic and applied sectors through university-industry cooperation.

Enabling Technologies

Improvement in the design of fermentation plants, the evaluation under field conditions of microbial-enhanced oil recovery, and the application of biotechnology to commodity-related production should bring commercial benefits in the next 5 to 10 years. Genetic engineering and selection of food stock are additional areas of rapid growth.

There was an extensive discussion of the following topics: (1) methods for the downstream processing of fermentation products by filtration and high performance liquid chromatography, (2) the scale-up of single-cell protein sources, (3) the automatic feedback control of fermenters by computers and selective electrodes, and (4) the use of microbes to enhance the rate and amount of oil recovered (enhanced oil recovery) from deposits.

Vivian Moses (Queen Mary College, UK) presented an overview of the need to improve oil recovery. Current methods recover approximately 35% of the oil from conventional wells and even less from heavy oil deposits and sands. Moses estimated that a 1% improvement in recovery techniques would yield $4 billion annually. Because water-oil interfaces have a high surface tension, the extrusion of residual oil by increased water pressure is not fully efficient. New methods are needed to decrease the oil-water interfacial tension, to increase the viscosity of water surrounding the oil, and to decrease the viscosity of the oil. One technique is to inject microbes into the well to synthesize surfactants and release gases.

For microbial enhancement of oil recovery, the following conditions must be met: (1) the microbes must tolerate reservoir conditions of 90°C, (2) the microbes must not plug the well pipes, and (3) corrosion and souring must be at acceptable levels.

Bohdan Bubela (Baas Becking Geobiological Laboratory, Australia) emphasized the need to test the microbes in simulated well conditions. Such simulations can reveal whether the microbes grow under the anaerobic conditions present in the well and how the well environment affects bacterial shape and metabolic demand. Practical experience in the field appears as important in oil recovery processes as elsewhere. Dr. Bubela's comments complemented those of speakers urging university researchers to interact directly with industry. H. Janshekar (Petrogenetic, Switzerland) reported the development of a glycolipid surfactant that is useful in reducing oil-water interfacial tension. Thomas Jack (NOVA Husky, Canada) described the use of membrane fragments from bacteria to break the oil-water emulsions after recovery of the oil from the deposits.

The panel discussions on fermentation were concerned with current commercial applications of fermentation technology to biomass conversion (alcohol and syrup production), synthesis of low molecular weight nutrients (amino acids, vitamins), single-cell protein production (e.g., Pruteen by ICI), and pharmaceuticals. Several presentations were related directly to improvements in fermentation technology.

Technological Advances

The design of modified oxygen electrodes, biosensors such as thermistors and ellipsometers, and bioelectrical-biooptical conductors are of high priority in the automation of fermentation systems and in clinical diagnoses. The successful development of such probes is essential for plant automation.

The following advances were emphasized:

1. The advantages of enzyme and cell immobilization processes over conventional fluid suspension systems,
2. The use of commercially available enzymes to catalyze novel reactions,
3. The development of thermistor electrodes to detect substrates in fermenters by continuous flow or to detect antigens such as insulin in biological fluids,
4. The application of polarized coherent (laser) light to measure the concentration of antigens in solution (ellipsometry), and
5. The application of electron-conducting biopolymers to industrial purposes.

Alan Rosevear (Atomic Energy Research Establishment [AERE], Harwell, UK) discussed cell immobilization's benefits and problems--particularly those related to biomass conversion. The existing processes for biomass conversion include agriculture, tissue

culture, and immobilized enzymes. Immobilization is useful only when a specific end-product rather than the entire biomass is desired, and when the enzymes required to make the product are available in an economical and stable form.

Because high biocatalyst concentration can be achieved, immobilization can offer the following commercial benefits:

1. Retention time in the reaction vat is reduced, with a resultant decrease in the concentration of side products,
2. Fine control of the reaction is improved because the process stops as the effluent leaves the reactor,
3. The concentration of the catalyst is regulated independently of the growth of the organism, and
4. The stability of the catalyst is increased.

Christian Wandrey (Nuclear Regulatory Center, Julich, FRG) showed that a process converting 70% of substrate to product per cycle of treatment with immobilized enzyme is of economic value (with l-leucine production). The loss of enzyme activity from poisoning was greater than that from thermal or viscosity conditions. Because of the high labor costs involved in the repacking or replacement of immobilized enzyme, the system should be stable for several months under operating conditions. A particular problem with the use of immobilized enzymes in food processing is the need to demonstrate that support matrices do not yield toxic substances under operating conditions.

There are two methods of enzyme immobilization: the use of calcium alginate beads for batch processing, and photo-induced crosslinkage of enzymes to resin sheets for continuous flow systems. From studies on alcohol production, Goro Oda of RAPAD (Japan), and Tomiaki Yamada of Japan Gas Corporation (JGC) concluded that either method is better than conventional batch processing. Alcohol production by the bead system was increased twentyfold over that obtained by conventional batch fermenters. The bead process proceeded for 4 months without requiring sterilization, and high alcohol concentrations were attained with a conversion yield of 95%. The photo-induced crosslink system uses polyethylene glycol with isophorone isocyanate bridges. The same crosslink system can bind proteins to a variety of materials, including paints.

Among the most interesting presentations was the discussion by Alexander Klibanov (Massachusetts Institute of Technology, US) of the application of conventional enzymes to catalyze unusual reactions. Although approximately 2,000 enzymes are known and 200 are available from commercial sources, fewer than 20 can be used in the kilogram quantities needed for mass production systems. Therefore, it is important to identify novel reactions that these 20 enzymes can catalyze. For example, Klibanov showed that glucose oxidase catalyzed the reduction of quinones (benzoquinone) to hydroquinone, that horseradish peroxidase converted phenols to catechols, and that carboxyl esterases catalyzed the transesterification of organic alcohols. Such reactions are economically advantageous for the production of optically active esters (having a chiral position) and for organic synthetic routes that may be particularly difficult (e.g., the selective hydroxylation of aromatic compounds). When novel catalytic properties can be predicted on the basis of the conformation and primary sequence of the protein catalysts, this strategy should become of great industrial interest.

A panel on bioelectronics concerned itself with the application of modified oxidation-reduction electrodes to detect solutes in aqueous solutions. For example, the immobilization of glucose oxidase on an oxygen electrode permits the measurement of glucose concentrations in a fermenter. The immobilization of bacteria that oxidize ammonia to nitrites (*Nitrosomonas* sp.) and nitrates (*Nitrobacter* sp.) on oxygen-detecting electrodes permits the amperometric determination of ammonia (Isau Karube, Tokyo Institute of Technology, Japan). Optoenzyme detectors have also been developed to measure the concentration of penicillin or serum albumin in solution. The system depends on the interaction of membrane-bound dyes (Cibachrome dyes or bromcresyl green) with the biological material and the resultant shift in maximal absorption characteristics of the chromophores.

Klaus Mosbach (Univ. of Lund, Sweden) reported on the potential applications of two devices, the thermistor and the ellipsometer. The thermistor allows the direct measurement of substrates that participate in exothermic reactions. Urea levels can be determined by the analysis of the heat given off by immobilized urease as it encounters the substrate. Antigen levels can be determined by the competitive binding of free antigen and peroxidase-linked antigen to immobilized antibody. Because oxidation reactions

are exothermic, heat is produced as peroxidase interacts with its substrate. As free antigen displaces the peroxidase-antigen complex, the thermistor detects less heat production. Such interactions have been used in the quantitative determination of insulin concentrations.

Ellipsometry provides a more direct measure of large antigens (cells). As a large antigen interacts with an immobilized antibody placed in the path of a polarized laser beam, the reflected light measures the increase in particle size of the antigen-antibody complex. The change in signal provides quantitative data on the antigen concentration in solution. If developed further, the technique could provide a tool to benefit the chemical, defense, and medical communities.

A Biotech conference will be held from 15 through 17 May 1984 in London, England, to consider developments in Europe. The Biotech 84 conference will be held from 10 through 12 September 1984 in Washington, DC, to consider worldwide developments.

J.F. Kerrigan
National Science Foundation
Washington, DC

THE STRUCTURE, DEVELOPMENT, AND EVOLUTION OF REPTILES

A special symposium on the structure, development, and evolution of reptiles was held in London on 26 and 27 May 1983. Sponsored by the Zoological Society of London, the Anatomical Society of Great Britain and Ireland, and the British Herpetological Society, the meeting had sessions on morphology, development, physiology, ecology, and evolution. The symposium was in honor of A. d'A. Bellairs (Professor of Anatomy, Medical School, Paddington, London) on the occasion of his retirement. Dr. M.W.J. Ferguson of Queen's Univ., Belfast, organized the meeting.

The opening paper was by Dr. P.F.A. Maderson (Brooklyn College of the City Univ. of New York), one of many former students of Bellairs at the meeting. Maderson noted that skin-shedding is the oldest observation on snakes known to man, yet little is known about the basic cytological evolution. The panbody synchronized patterns of cell proliferation and differentiation in squamate are unique among the epidermis of vertebrates, and there are few aspects of squamate skin shedding analogous to any metazoan epitheliums, except the terminal shedding of some cells. With respect to hormonal control, the thyroid appears to be the only gland directly involved with shedding, but the relationship between the two is not clear. Maderson suggested that hormone activity is modulated by environmental temperatures, but the mechanism of action is not known.

G.L. Underwood (City of London Polytechnic) presented an interesting study, partly statistical, on the scleral ossicles of certain lizards. His data indicated the potential usefulness of the ossicles in systematic and evolutionary analyses. However, he pointed out that in spite of the statistical evidence and computerized data, care should be taken in using such definite findings instead of other recognized systematic cues. It was refreshing to hear a leading systemic herpetologist, who had just presented almost overwhelming evidence on a good tool for taxonomy, caution researchers against using only that approach in systematics. There is little question, however, that scleral ossicles are attractive material for formal systematic and evolutionary analyses in lizards. There is considerable overlapping in patterns; but with the help of a computer, they can be defined well enough to be classified almost unequivocally and the evolution understood.

R. Presley (University College, Cardiff) presented a comparative study of lizards, mammals, and the primate tetrapod tympanic membrane. He reviewed the probable evolution of each and their differences and similarities. Presley demonstrated that lizards and mammals differ greatly in the site of the external meatus and in the position and anatomy of the membrane during both development and adult life. Interestingly, in neither group is the first-pouch or first-cleft (spiracular) contact used in the development of the membrane. His findings support the earlier work of Gaupp and appear to contradict scientists who hold that the mammalian form evolved from a sauropsid-like stage in the therapsids. No assumption can be made with respect to a common "primitive tetrapod" as far as patterns of development are concerned.

Piscivory in turtles and the evolution of the long-necked Chelidae were reviewed by P.C.H. Pritchard of the Florida Audubon Society. He noted prey-capture techniques used by turtles that feed on fish and drew comparisons with the ways humans fish--angling or luring, netting or trawling, and spear-

fishing or harpooning. Pritchard described several morphological specializations of the neck and the postcranial parallels that were found in various turtles. Of particular interest, in addition to the elongated necks, are the relatively narrow, elongated heads and jaws, the enlarged hyoids, anteriorly placed orbits, and in some species a specialized rib head to accommodate enlarged longissimus dorsi muscles. Although adapted for piscivory, some long-necked Chelidae feed on other animals, particularly when young, and the diet of some species contains fewer fishes than does that of other marine or even terrestrial forms. Pritchard concluded that neck elongation may have evolved quite independently in the various Chelidae.

J.M.F. Landsmeer (Rijksuniversiteit, Leiden, the Netherlands) presented a paper on the morphology of the anterior limb of the reptile *Varanus*--an in-depth study of a complicated three-dimensional mechanism, commonly known as the sprawling gait. The mechanism makes specific demands on the linkages of the articular chain; in the transmission and transformation of movements, the cubito-carpal mechanism is of prime importance. The elbow, radius-radiale, and ulna-ulare-pisiform joints are functionally independent systems. The interesting asymmetry of the hand was described by Landsmeer; he emphasized the functions of the intrinsic muscles, particularly as related to the so-called claw traction and narrowing phenomena. Landsmeer also compared the structure and function of the complicated system with that found in humans.

B.K. Hall (Dalhousie Univ., Halifax, Nova Scotia) discussed skeletal differences in reptiles; underlying development processes were emphasized. Reptiles apparently lack secondary cartilage, although this has not been studied in depth. Hall suggested that either their periosteal cells are unable to synthesize cartilage-specific product, or they cannot respond to the mechanical stimulation that evokes such synthesis. Ectopic cartilage and bone are well developed in reptiles, as demonstrated by sesamoids and cardiac cartilage. Hall referred to the timing of tissue interactions in the induction of Meckel's cartilage and to the possible importance of shifts in timing of developmental processes in skeletal evolution.

S. Bryant (Univ. of California, Irvine) described her work with K. Muneoka and others on regeneration and development in vertebrate appendages. Bryant presented data showing that developing and regenerating limbs use similar patterning mechanisms during their outgrowth. The conclusion was that in patterning models for the study of developing and regenerating limbs, the rules of the polar coordinate model can explain the behavior of the cells involved. This was nicely demonstrated in definitive investigations by the Irvine group. In concluding, Bryant considered the possibilities of inducing limb regeneration in higher vertebrates.

The next speaker, L.S. Honig (Univ. of Southern California, Los Angeles), continued the discussion of limb generation patterns. Honig noted that while the patterned outgrowth of reptile, bird, and mammal amniotes had strong resemblances, there were also significant differences--particularly when one considers lower vertebrates such as the Amphibia. The higher vertebrates lack the major intercalative and regenerative abilities seen in Amphibia. Also, the region responsible for positional information along the antero-posterior limb axis is in the flank in amphibians rather than in the limb bud. Honig concluded with findings that the retinoid compounds of vitamin A have marked but different effects on pattern formation in amphibian and avian limb systems.

Ferguson, another of Bellair's protégés, read an interesting account of craniofacial development in the alligator *Alligator mississippiensis*. Facial morphogenesis begins at day seven, when the optic, otic, and nasal placodes appear and three branchial arches are seen. By day nine, five branchial arches are present. Ferguson then went on to demonstrate the subsequent development of the nasal and maxillary processes, indicating some essential differences observed in different crocodilian species. Of particular importance in Ferguson's studies has been the development of semishell-less culture techniques and the teratogenic induction of absent lower jaw and tongue in alligator embryos, which gave rise to the first longitudinal study of palatogenesis in any animal.

The problem of enamel gene product formation (amelogenesis) in reptiles has been quite controversial during the past 100 years. M. Zeichner-David presented a paper by her group at the Univ. of Southern California. She discussed some of the evolutionary aspects of enamel gene products. New evidence suggests that epithelial differentiation and subsequent enamel production appear to be homologous in various vertebrates: shark, wrasse, eel, pike, mouse, rat,

rabbit, hamster, pig, cow, monkey, and man. Using specific polyclonal antibodies directed toward purified enamelins and amelogenins, biochemical characterizations of enamel proteins, and recombinant DNA methods, the researchers confirmed the work of Harold and colleagues: the development associated with amelogenesis is homologous throughout the vertebrates.

K.W. Jones (Univ. of Edinburgh) presented a paper on the evolution of specialized sex-determining chromosomes--of particular importance in snakes because the evolutionary elaboration of specialized sex-determining chromosomes is found in some families of snakes and not in others. R.A. Avery spoke on the role of thermoregulation in lizard growth. He concluded that increased growth was due entirely to increased voluntary food consumption and that thermoregulation had no effect on net growth conversion efficiency. No data were presented on food elimination or energy expenditure.

R.A. Coulson (Louisiana State Univ., New Orleans) read a paper on the importance of metabolic rate and anaerobic glycolysis in determining the habits of reptiles. He concluded that the primary difference between a warm-blooded and cold-blooded animal is more one of chemical engineering than one of chemistry. F.E. Russell (Univ. of Arizona, Tucson) described the structural evolution of the venom apparatus of snakes as it correlated with the functional evolution of the venom. The two cannot be considered separately; one caused the other. He also reviewed the evolution of snake venoms on the basis of their chemical and pharmacological properties.

V. Lance (Tulane Univ., New Orleans) noted that the common feature of gametogenesis in reptiles is elevated androgen levels in the plasma during spermiogenesis. He concluded that despite considerable species variation in both testicular cycles and plasma testosterone concentrations, the androgen cycle in squamates is basically similar to that in Chelonia and Crocodilia in that they all peak at spermiogenesis. A. Brae (Alyth, Scotland) reported on a captive breeding program for an endangered crocodile species, *Gavialis gangeticus*; the design and construction of a facility for the crocodiles; breeding techniques; and the results after the first 4 years of the project.

G.J.W. Webb (Univ. of New South Wales, Kensington, Australia) presented an important statistical study on the sex ratio and survival of the Australian freshwater crocodile, *Crocodylus johnstoni*. Sex appears to be determined by incubation temperatures. When the temperature was the highest or lowest consistent with survival, the offspring were generally females; males were usually born when temperatures were between the extremes. Obviously, embryos with the highest death rate were females. Low incubation temperatures were consistent with slower development. The longer incubation period and slower development also resulted in a longer exposure of the eggs to environmental changes and thus greater dangers. However, sex ratio selections are also modified by survival considerations. Webb put his fascinating findings together to show that in spite of numerous influences, the sex ratio remains relatively constant in the species.

Thermoregulation in the Nile crocodile, *Crocodylus niloticus*, was discussed by J.P. Loveridge (Univ. of Zimbabwe, Harare, Zimbabwe). He described the differences in juvenile and adult crocodiles, methods of insulation, and mouth gaping as a means of evaporative cooling. O. Rieppel described a concept of miniaturization of the lizard skull, based on a comparative analysis of the head anatomy of fossorial lizards. D.B. Norman (Oxford Univ.) described the cranial morphology and evolution of ornithopod dinosaurs.

Prof. Bellairs spoke last. Few, if any, herpetologists of this century have contributed more to the science than he. Bellairs noted the development of our knowledge about things reptilian and observed that in spite of several thousand years of study, there were still reptilian structures and functions about which we know little. Finally, he suggested that science might profit from a more interdisciplinary approach.

F.E. Russell
Univ. of Arizona, Tucson

COMPUTER SCIENCES

ROBOT CONTROL SYSTEMS AT SEPA

The Società di Elettronica per l'Automazione (SEPA, Turin, Italy) is an independent company of the Fiat Group. Its main product lines are industrial automation, industrial instrumentation, services automation, ship automation and instrumentation, electrical power plants

automation and instrumentation, and weapons systems. SEPA was established with its present name in 1976 but originated 20 years earlier as Fiat's Electronics Studies and Research Center (ESRC). This article deals with robot control systems for industrial automation.

In 1973, SEPA (then ESRC) began developing a control system for a spray painting robot with mechanical parts made by Trallfa A/S (Byrne, Norway). The control system used a 32K core memory of 16-bit words. The control unit was named IDRA-12 and the central processing unit was called ULP-12. Later, IDRA-15 was developed with the same mechanical parts but a different computer, a microprocessor. The control system provides continuous path control; the three spatial coordinates of points along the path are determined separately but simultaneously. One feature of the system is a learning phase using manual teaching. During the teaching, conducted directly by an operator, the robot wrist is driven through its motions; the coordinates of the robot arm are selectively recorded in memory. With Lagrangian interpolation, the number of points originally recorded along the path can be greatly reduced.

In 1978, SEPA developed a point-to-point control for a system marketed by Fata (Italy). A single microcomputer, the INTEL 8080, was used for the control system. The control unit was given the name Cobra-32. Fata markets this complete Automatic Guided Vehicles system, including the carriers for moving parts to be assembled.

The characteristics of Cobra's axis movement include:

- Linear interpolation on all axes, with or without deceleration onto the programmed point,
- Maximum simultaneous speed on each axis, with or without deceleration onto the programmed point,
- Correlation between the angular positions of different axes,
- Ten programmable speeds for each movement section,
- Positioning speed control throughout the movement,
- Controlled acceleration and deceleration, with axis values calibrated to the specifications of the machine.

To improve the robot's learning procedures and its interface with the work environment, the Cobra's programming language (BASIL) is directed to both the handling of machine tools (axis movement, input and output field signals), and the processing programs and data (BASIC instructions, simplified and with greater emphasis on logic variables).

Three learning techniques are permitted by the language:

- Learning in the field of significant movement distances imposed manually, and the output on/off signals related to each movement,
- Learning through off-line programming, using the complete set of instructions and entering the coordinates as values calculated on paper,
- Mixed learning--i.e., in-the-field learning--followed by the addition of the complete set of BASIL instructions to the recorded program.

A robot is usually a station in a machining line or the junction of several lines; thus, the Cobra controls the following: (1) the robot, (2) the control system's intermediary function of conversing with the other control equipment, and (3) through direct programmable logic, the adjacent lines.

The operator's console consists of a monitor, an alphanumeric keyboard, pushbuttons, a selector switch, and remote controls. The 12-in. monitor can display 128 characters in small format on a 7- by 9-point matrix. Messages containing information that needs to be monitored are updated every 100 ms. Other messages are presented when requested and held until a further request is made. A message called the standard message appears automatically each time there is a change in the operating mode or operations are executed in this mode on the controller. Optional messages, called request messages, appear when requested by the operator. Messages due to malfunctions of the control unit are known as alert messages.

The alphanumeric keyboard has the following key arrays: the most commonly used numerical control letters; decimal figures, special characters, and an "enter" key used to close a string of entered characters or stop the execution of instructions; and special or service characters used in the entry of various handling commands.

The pushbuttons and selector switch are used to select the control console operating mode, entry of the program test and other tests, and the start or conclusion of operational actions on both the control console and the robot. The console also has a feed rate override selector switch. The remote controls are entered by a movable button strip used for manual control of the

axes and for entering the learning instructions relating to the type of movement, its corresponding speed, and the on/off signal to the robot during the work cycle.

The key features of the programming language include the sequential correlation of on/off signals from and to the field, the timing of events with a base generator, the availability of instruction subroutines, and the variety of movement modes for the machine axes. Programming can be done as follows: (1) entirely through the control panel keyboard--the instructions are expressed in their symbolic format without dedicated keys, (2) entirely by learning in the field, using the hand-held button strip, or (3) in the mixed mode--learning plus keyboard--with the possibility of various operating sequences. In-the-field learning programming uses only a few of the instructions available.

If compatible with the application, Cobra-32 can be programmed very simply by in-the-field learning only, ignoring the existence of a symbolic programming language. When machining problems are more complicated--in the interconnection between the robot and its environment, for example--all instructions are available.

SEPA is developing Cobra-18, a more sophisticated version of Cobra that uses a single ULP-18, 32K, 16-bit word minicomputer. Cobra-18 will perform point-to-point or continuous-path control. By adding another microprocessor with memory, the system can carry out programmed logical control.

J.F. Blackburn

THE THIRD INTERNATIONAL CONFERENCE ON ENGINEERING SOFTWARE

The Third International Conference and Exhibition on Engineering Software featured speakers from 22 countries and exhibits from some 25 companies. Held from 11 through 13 April 1983 at Imperial College of Science and Technology London, the conference provided a forum for the discussion of recent advances in the use of computers in mechanical engineering. Most branches of mechanical engineering were discussed; there were also papers on civil, structural, marine, manufacturing, and chemical engineering. Fourteen sessions were held during the conference; this article highlights one paper from most of the sessions

"Microcomputer Based Computer Aided Design System Applications in Engineering Education," by B.S. Charles (Washington Univ., St. Louis, MO) was one of three papers given in the engineering software session. The software developed at Washington Univ. is used in an introductory structural design course and covers analysis and design of trusses, continuous beams, and plate girders. Special purpose programs were produced for the inexperienced user and provided accelerated design experience. Charles maintained that the underlying principles of the engineering software must be understood. The educational computer aided design (CAD) software was designed to enhance classical teaching methods. Such software is a valuable teaching aid because it provides immediate feedback and leaves engineering decisions to the user. The student is exposed to CAD, computer graphics, and microcomputers.

The system is designed to enable students to concentrate on user-computer interfacing, consisting of menus, unambiguous and informative input prompts, easy to understand textual reports, input data checking, and color graphics feedback. Color was used to amplify and clarify analysis results.

Among the advantages of a single-user microcomputer are good response and avoidance of long queues for peripheral devices, lower operation and maintenance costs, and the personal environment. The software at Washington Univ. was developed on an Apple II Plus microcomputer with 64K bytes of random access memory, two flexible disk drives, a color video monitor, and an 80 character per second dot matrix printer with graphics capabilities.

A paper on "GRAFFIC--A Computer Package for the Interactive Graphical Representation of Fluid-Flow Phenomena" by Nikos C. Markatos and Coulis A. Pericleous (Concentration Heat and Momentum Limited, London) was one of four presentations on mechanical engineering. GRAFFIC is a three-dimensional graphics computer package which provides interpretation and display facilities for numerical predictions of phenomena involving fluid-flow and heat/mass transfer. It is designed for use as a pre- and post-processor for solution methods of the finite-domain or finite-difference type. GRAFFIC operates interactively, using a storage-type graphics terminal with associated hard-copy units if required. Communication with the user is by a series of

meaningful prompts designed to make operation self-explanatory.

Facilities provided by GRAFFIC include representation of the flow geometry and solution mesh, contour maps and surfaces of scaler fields, and vector fields represented either by vector maps on selected planes or by vector lines or stream lines. For two-phase computations, GRAFFIC provides separate representation of the velocities and other properties of each phase.

Several view options are provided, including perspective from a specified viewpoint; oblique views; two-dimensional side, top, and end views; and a stereoscopic effect provided by two perspective views at a small displacement. A description of the structure and organization of GRAFFIC was given and examples of its application were discussed.

In a session on structural engineering, R. Delpar (the Polytechnic of Wales) spoke on "Vibration Analysis of Elastic Rotational Shells Using Microcomputers." The paper concerned subjecting thin rotational shells to static and dynamic loads. (The finite element method for rotational shell analysis was discussed by Love [1944].) A computer program that always uses core memory frugally has been devised. An efficient eigenvalue-economizer routine has been developed to reduce the iteration time. The routine can select the masters analytically at a given cut of frequency (Reissner, 1955). Thus it is easier to store and run the routines on modern microcomputers. Several well-established examples have been tackled, including a long cylindrical shell analyzed as a beam, a short cylinder fixed around both edges, vibration of cones in flexure, bending vibrations of thin disks, and natural frequencies of the cooling tower.

Fourteen papers were presented on finite elements and boundary elements; two are summarized below. "Finite Element Upsetting Analysis of a Ring: An Incremental Solution to the Contact Problem" was discussed by Ibrahim M. Al-Khattat (Yarmouk Univ., Jordan). The ring test has been devised to measure friction parameters under extreme pressure conditions--metal forming processes, for example. However, erroneous assumptions are used to develop and interpret the test. The continuum definition of stress is violated not only by the test theory, but also by the current concepts of friction and lubrication. The author proposed a general solution for measuring stress--a solution based primarily on the continuum definition of stress as a local quantity. An experimental procedure, following Bridgman's shear-compression fracture tests, is proposed to measure frictional properties in a new format. The resulting information is introduced in the analysis as explicit displacement or traction boundary conditions. The incremental nature of the nonlinear boundary value problem involving the deforming media in contact is used to generate a discretized approximation of the state of stress and the deformation along the contact surface at the end of each solution increment. An important consequence of the approach is that the symmetry of the stiffness matrix in the finite element analysis is ensured, resulting in considerable computational savings. Another advantage of the proposed method is the elimination of nonphysical corner stress singularities. Moreover, recognition of the local nature of contact stresses implies that the proposed method is applicable to any geometry of contact.

The finite element analysis of the upsetting of the standard steel ring is carried out using an elastic-plastic finite deformation theory and the new method of contact modelling. Computer graphics are used to display stress distributions. The results point out the serious shortcomings of the standard ring test and the present friction measurement methods in general. The proposed method can be used in computer-aided design of metal forming processes and in the analysis of many complex boundary value problems involving contact.

E.A.W. Maunder (Univ. of Exeter, UK) discussed "Design of Structural Continua by Finite Element Analysis of Equilibrium Models." Most finite element programs applied to structural analysis use displacement models and treat node displacements as the primary unknowns. However, in many cases the designer would prefer to work directly in terms of stress-resultants and stress fields that satisfy the equilibrium conditions.

Maunder proposed a finite element model using equilibrium elements within which stress fields are defined in equilibrium with edge stress resultants. The proposed model is suitable for plane stress or strain problems with linear elasticity. The edge stress resultants are classified as basic (normal force, shear force, and moment) and higher order. The higher order stress-resultants supplement the basic class and involve edge stresses that are in self-equilibrium. The stress resultants can be treated as element unknowns, and

the model can be analyzed using the flexibility method. In the flexibility method for finite elements, statical indeterminacy and procedures for solution of corresponding force paths are defined. Force transmissions between elements are through corner nodes. The method can be used with conventional displacement elements but is unsuitable if "strong" equilibrium is required. In this case equilibrium must be satisfied everywhere, including element edges.

A computer program has been developed to implement this method of analysis. The main features of the program include the incorporation of triangular elements having six or nine degrees of freedom of edge stress resultants and the selection of suitable force paths from an interior graph embedded in the model. Algorithms for path selection are based on topological properties of the graph. A numerical example was presented to demonstrate both the feasibility of the method and its potential in structural design, particularly when the lower bound theorem of plasticity can be applied.

Ten papers were on simulation. "A Theoric-Experimental Computer Aided Method for the Prediction of Overhead Line Dynamic Behavior at High Speed" was presented by R. Muguerza et al. (Univ. of Navarra, Spain). An important problem in high speed trains is the quality of contact between the overhead line and the pantograph. The loss of contact due to dynamic interaction causes damage in power units and wear in the line. A great deal of work on predicting current collection system behavior has been done during the last two decades by most important railway administrations. Muguerza's paper presented a mathematical model for computer simulation of the problem.

The overhead and the pantograph were analyzed separately to validate the mathematical models developed for each one. The checking included linear and nonlinear dynamical behavior and wave propagation along the overhead line; theoretical and experimental results were compared.

The overhead line was studied by matrix methods. The model overcomes most of the principal deficiencies of previous models, taking into account, among other things, flexural stiffness of the droppers (leading from the overhead line to the pantograph base) beyond the pretraction load, and the possibility of a double contact wire.

A model with seven degrees of freedom has been developed for the pantograph. The experimental transfer functions have been fitted in a range from 0 to 30 Hz.

The representative equations of the overhead pantograph system are integrated in time by an implicit method. Contact condition between the pantograph and wires is taken into account by means of Lagrange multipliers, whose physical meaning is that of the force of contact between them. In addition, the method takes into account displacement of the pantograph base, contact prediction, and droppers disconnection. Theoretical results were compared with experimental measurements.

One of six papers on computer aided design/computer aided manufacturing (CAD/CAM) was "The Software Interface Between CAD and CAM," by P.F. McGoldrick (Univ. of Nottingham, UK). The speaker said that because of the technical and organizational difficulties involved, the interface between CAD and CAM has not received the attention it merits. Currently, the only area with established software is the interface between some CAD systems and the numerically controlled machining sector of CAM. McGoldrick argued that even in this limited area the best approach has not been adopted.

The role of the part-programmer is to interpret the designer's requirements as stated on the drawing and to convert them into an ordered form for processing and post-processing into the final instruction set used to drive the numerically controlled tool. The task requires knowledge of two areas: a method of planning the particular process being used for production, and a procedure for modelling the path generated by the relative motion between the work piece and the tool. Algorithms are being developed to meet the first of the requirements; McGoldrick described some graphics techniques to give a computer-driven solution to the second.

McGoldrick argued that the part-programmer's task can be replaced by software. He further maintained that if the organizational gulf between design and manufacture can be bridged, then there is no reason the designer cannot request the computer to produce a numerical control tape image that has been fully planned, processed, and post-processed entirely automatically. The designer can then visually check that his requirements have been met.

In hydraulics, A. Das Grupta (Asian Institute of Technology, Bangkok, Thailand) spoke on "Development of a Solute Transport Model for a Multi-layer Ground Water Basin." Many groundwater basins face the problem of salt contam-

ination in the producing areas if usage is not properly managed. The migration of salt water into fresh water formations is mainly due to the reversal or reduction of the piezometric head gradient, which allows heavier saline water to move into the regions of permeable formation where there is fresh water. The contamination may be: (1) seawater in coastal areas, (2) saline water that was trapped in sediments during deposition, or (3) saline water that invaded the sediments during periods of high sea elevation in past geologic times. One must first understand the mechanism of contamination, then identify the source in order to predict the spatial and temporal variation of salinity under different control measures.

The method described deals with the development of a quasi-three-dimensional finite difference solute transport model for a multilayer groundwater basin. The goal is to obtain a model that combines a sound theoretical basis, simple mathematical manipulation, and computer programming, and that closely represents the hydrogeological situations in a specific problem area in Thailand.

Three distinct processes contribute to transport: convection, mechanical dispersion, and molecular diffusion. The anticipated hydrodynamic behavior of a multilayer system is as follows: with an initial piezometric head distribution in the system as static, if water is withdrawn from any aquifer the piezometric head drop in that aquifer occurs first locally and later spreads to other areas in the aquifer as pumping is continued, disturbing the equilibrium of the system.

The interaction between the aquifers is included through leakage flux calculated on the basis of the piezometric head gradient existing across the intervening aquitards. The model has the flexibility of using nonuniform grid spacing and time step for an extensive regional basin. The model applicability to the actual field situation was checked by solving three hypothetical problems involving two confined aquifers.

In the session on data bases, "A Virtual Storage Data Management System for Finite Element Analysis on Micro's" was presented by E. Backx and J.P. Rammant (Catholic Univ. of Leuven, Belgium). Microcomputers and minicomputers have limited internal memory capacity. All finite element analysis programs therefore make extensive use of complicated overlaying techniques and common data blocks. With such a structure, it is difficult to recover from program errors.

The speakers presented an intelligent data management software system to overcome the problem of micros' limited memory. Written in BASIC language, the system uses a structured data access method that stores all input arrays as text on external storage (hard disk). A small subprogram keeps track of input, editing, and additions to the input data. Appropriate pointers and array names replace the normally dimensioned matrices. Through the analysis, virtual pages of the data are loaded and shifted in the various program modules (dynamic allocation). In addition, the results are stored in the pages, facilitating the post-processing work. The methods used have been implemented on Wang computers.

In the civil engineering session, L.A. Wood (Department of Civil Engineering, Queen Mary College, London) presented a paper on "Freewall--A Membrane Retaining Wall Design Package for Micro-Computers." "Freewall" has been developed as an easily used, truly interactive software package for designing sheet pile and diaphragm walls. The program was written in BASIC language and is portable, with little alteration, between most 32K byte microcomputers. Full data editing, disk storage, retrieval of data and results, inspection of results on a monitor screen or hard-copy from a printer, and other features attractive to users have been incorporated in the code.

The comprehensive capabilities of the program were illustrated with respect to several typical wall and soil configurations, encompassing multi-tied walls, sloping and submerged back-fill, and the development of wall friction and adhesion.

Engineering Software III--Proceedings of the 3rd International Conference, Imperial College, London, England (April 1983) has been published by Springer-Verlag.

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C.L. Blackburn

ELECTRONICS

MASSIVE NEW INVESTMENT AT HIRST RESEARCH CENTRE PAYS DIVIDENDS

A massive internal redirection is under way at the General Electric Co., Ltd. (UK) Hirst Research Centre. A new management team headed by D.H. Roberts, General Electric Co. Ltd.'s Head of Research; D. Hooper, Hirst's Director; and D. McCaughan, Director, Solid State Device Laboratory has concentrated on the research and development (R&D) of solid state microwave materials and devices.

Located in Wembley, about 10 miles northwest of London, Hirst has grown from 520 employees in 1980 to over 830 today. Dr. C. Hilsum, internationally acclaimed for his work in III-IV materials while at the Royal Signals and Radar Establishment, is now Hirst's chief scientist. Dr. C.E.C. Wood, who spent 5 years in charge of the molecular beam epitaxy (MBE) facility at Cornell Univ. is now in charge of the Hirst solid state microwave group. Clean room facilities recently installed have been outgrown, and a £1.7 million (about $2.7 million) new 5,000 sq ft clean room is being added. Since 1978, the solid state microwave program has grown by an average of 70% per year. Current year expenditures for the solid state microwave R&D program are an impressive £5.6 million (about $9 million).

Fundamental Research

In addition to the applied research and exploratory development noted above, the Hirst Centre supports a sizeable basic research effort whose underlying theme is the physics of small structures. In molecular science (2 to 3 nm building blocks), researchers are working on the theory of charge carrier transport in organic crystals and films. A program in Langmuir-Blodgett films seeks robust dielectrics and "active" molecules. Investigations into the mechanisms of depth perception by monocular vision may lead to better sensors across the spectrum.

The largest of the long range research programs is electron physics in the submicrometer region. Research topics include: (1) thermal properties of fine silicon wires, (2) magneto-thermal conductivity of metal oxide semiconductor (MOS) structures and III-V heterojunctions as related to electron-phonon interactions, (3) thermal analysis of silison on sapphire (SOS) interface quality, (4) quantum noise in very fine wires, (5) quantum transport in devices near threshold, (6) novel devices' structures obtainable with MBE, and (7) coherent x-ray sources for very fine line lithography. The experiments with fine silicon wires are based on laser-induced thermal pulse excitation near the midpoint of a silicon pillar. The above efforts are characterized by longer range goals than are typical of an industrial research laboratory; some projects begun earlier are now coming to fruition. For example, research on high temperature contacts to semiconductors is now producing results. Although the use of amorphous metal films as diffusion barriers is not new, Dr. M. Kelly and colleagues reasoned that the correct amorphous metals may be successfully used as high temperature Schottky barriers. Kelly sought an amorphous alloy that had as a primary characteristic glass-forming ability over a wide range of deposition conditions. The choice of alloy must also be compatible with semiconductors and have a very high transition temperature, above which grain boundaries may appear. (Grain boundaries act as highly effective diffusion ducts through which over-plating metals migrate into the semiconductor.) Some researchers have used various metal silicides because of high stability and slow diffusion kinetics. But metal silicides also exhibit excessive resistivity and therefore are not suitable for very high speed devices. After investigating many metals and alloys, Kelly chose $Ta_{0.65}IR_{0.35}$.

The films were sputter deposited at 10 nm/min from composite targets; a triode direct-current gun was used in an Ar atmosphere at 1 Torr. The semiconductor substrates were held at room temperature to prevent any polycrystalline formation in the films. Composition was determined by x-ray fluorescence analysis, and the films' amorphous nature was ascertained by x-ray diffraction. Schottky diodes were made on both Si and GaAs n-type semiconductors. Films of 50 to 500 nm were deposited and gold plated. They retained complete structural integrity after 24 hours at 500°C. Only after 24 hours at 600°C was Ga outdiffusion observed; gold indiffusion was not found. After 24 hours at 700°C, chemical mixing was observed. The silicon results were similar at 700°C.

The films were also thermally cycled in air; at 600°C, oxygen uptake was noted in amorphous regions not covered with gold. At 350°C, no electrical changes were apparent in any of the films. When the 350°C test for periods of 24 to 40 hours was completed, the diodes were elevated to 500°C for

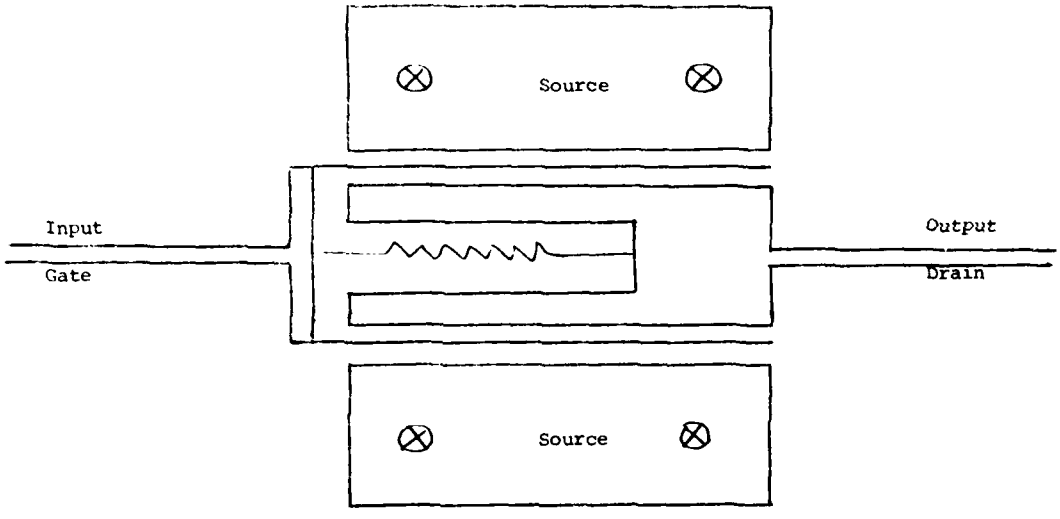

Figure 1. Integrated circuit microwave amplifier.

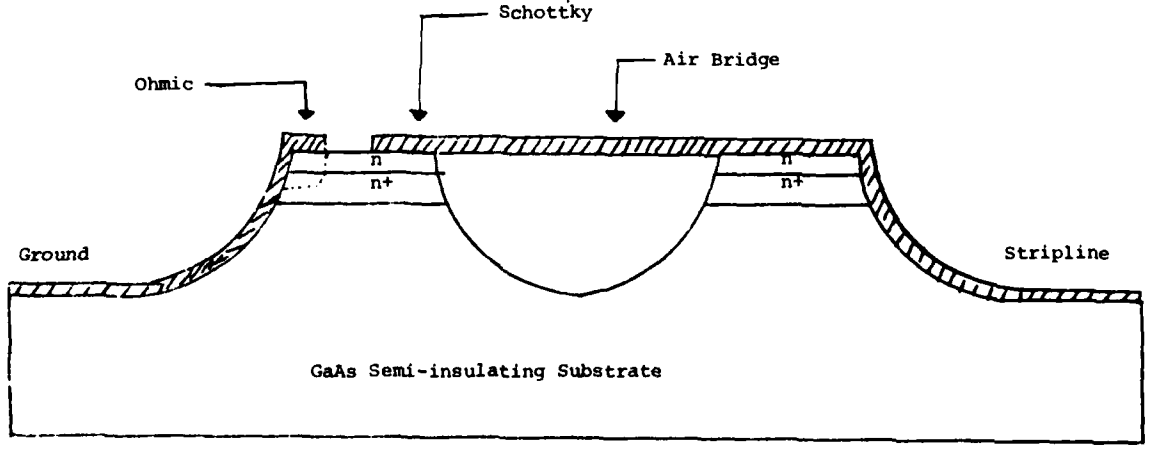

Figure 2. Mesa structures.

2.5 hours. Those on GaAs experienced a barrier height drop from 0.79 eV to 0.76 eV and an ideality factor change from 1.05 to 1.15. Silicon devices experienced a greater degradation of barrier height. After 32 hours at 450°C the silicon diodes had barrier heights of only 0.49 eV. In all cases, thermal degradation of the electrical characteristics was a result of action at the interface; the films remained amorphous, and no interdiffusion was found. These soon-to-be-published findings are the first correlated electrical and structural studies of Schottky barriers operating at high temperatures. Results have encouraged the investigation of amorphous films for ohmic contacts.

Applied Research

As GaAs wafer sizes continue to increase, the uniformity of the plasma-deposited Si_3N_4 passivating encapsulant degrades, and the differing thermal coefficients also contribute to blistering of the encapsulant film during thermal activation anneals. Therefore, researchers are seeking a capless annealing technique. J. Grange and D. Wickenden have found that 800°C capless anneals in arsine yield insufficient activation efficiencies, while 900°C anneals produce layer thinning caused by evaporation of gallium. The gallium evaporation in turn introduces an unwanted increase in surface conductivity. While others have resorted to covering one GaAs wafer with another (a proximity effect) and annealing in a hydrogen atmosphere, the Hirst group was unwilling to accept the resultant deterioration of surface morphology near the wafer edges. The solution was to combine the proximity effect with an arsine atmosphere. Activation efficiencies of up to 100% have been obtained with silicon implants of $4\times10^{12}/cm^2$.

The use of two feedback-controlled injection lasers as microwave-millimeter wave signal generators and oscillators is gaining momentum in Britain (see *FCN* 37-4: 133-140 [1983]). J. Barnard (recently of Cornell Univ.) has a novel approach to improve the stability and tracking characteristics of devices. He uses a transverse junction striped heterojunction structure that has a stripe width equal to the diffusion length of the carriers. The back-to-back lasers so formed are similarly heat-sunk by a gold-filled via hole beneath the stripe. Acceptors are diffused beneath the region subsequently covered by the ohmic contact stripe. As lateral diffusion also occurs, the lasing area is just outside the strain induced at the edges of the stripe. Envisioned improvements include modulation doped and multiple quantum well structures.

K. Wilson has been analyzing GaAs microwave field effect transistor (FET) performance for several years. He has concluded that Miller feedback capacitance is a major factor limiting device performance. To reduce feedback capacitance, he has recently fabricated GaAs FETs using a gate channel recess nearly as long as the source-drain spacing (i.e., several gate lengths). The devices performed well. Using 1.0-μm-long gates of 300-μm periphery, Wilson obtained 18-dB gain at 10 GHz. The noise figure at 10 GHz was 1.9 dB, while the associated gain was 8 dB. Such performance figures heretofore have been possible only with devices characterized by submicrometer control gates. The use of asymetrically located recesses (e.g., extending toward the drain but not toward the source) may further improve device performance. The technique is thought to be applicable also to submicrometer gate length devices.

A novel integrated circuit microwave amplifier was built with the above device (Figure 1). The amplifier has two gate "fingers" of 150 μm each and is fed on one end. The drain is between the gates, while the sources occupy the outside edges and can be grounded by holes. The drain metallization is physically severed along the line of symmetry at the gate end. The implantation of donors in the region between the gate buss and the drain metallization creates a negative feedback resistor, which significantly improves the operating bandwidth of the device. Thus, in an area no larger than the device itself, a feedback microwave integrated circuit is formed. The devices are also being incorporated into a distributed (e.g., traveling wave) amplifier where direct current to 14 GHz performance is sought.

While GaAs mobility is typically several times that of silicon, parasitic effects have often frustrated GaAs device and circuit designers; the expected higher frequency performance has not always been obtainable--particularly in millimeter wave integrated circuits. Recently, Wilson and his colleagues have significantly reduced parasitic losses in microwave-millimeter wave double balanced diode mixer circuits. Each diode consists of two identical and adjacent mesa structures, as shown in Figure 2. One mesa has an ohmic contact made over a part of its surface and extending into the n+ region

beneath. The contact is then metallized with the metallization passing down the side of the mesa and joining a ground plane at the surface at the mesa base. A Schottky contact is made on a remaining part of the top surface of the mesa. Rather than bringing its metallization down the side of the mesa and incurring parasitic losses to the n and n+ regions, an air bridge is made to the adjacent mesa. Since the n and n+ regions of the mesa are floating (i.e., not grounded), the metallization is safely brought down the side of the second mesa without excessive parasitic loss. Over a radio frequency input of 9 to 11 GHz, there was a 5-dB loss when the intermediate frequency output was 500 MHz.

Other results of GaAs device research include what are believed to be the first PiN diodes, which outperform silicon PiN diodes. Over the 5- to 15-GHz spectrum, the GaAs devices exhibited 27 dB of isolation and 0.7 dB insertion losses when used as switches in a phase shifter. Switching speed was less than 1 ns and probably much better. (Test equipment limitations precluded exact measurement.) Drive current requirements are a penalty for such performance. Whereas silicon devices typically require 2 mA, the GaAs devices require tens of milliamperes. The devices were fabricated by metal organic chemical vapor phase deposition (MOCVD) techniques. Other MOCVD-based device research includes impact avalanche transit time (IMPATT) devices.

Silicon device research includes bulk complementary MOS (CMOS) and SOS CMOS devices. CMOS R&D includes fabrication of devices using 1.0-μm lithography. Other CMOS work is directed toward multilayer metallization techniques; a 5,000 usable gate array is planned.

Silicon bipolar results are impressive; 4-GHz frequency dividers have been built with walled emitters and base region contacts on top of low capacitance Si_3N_4 regions. A low temperature polysilicon deposition technique combined with a solid state epitaxial regrowth of the poly to crystalline material is soon expected to provide an emitter-coupled logic (ECL) configured, 5.5-GHz divider. Transistors used for the divider exhibit an f_τ of up to 16 GHz.

M. N. Yoder

SENSING BY FIBER OPTICS COMES OF AGE

The world's first joint conference and exhibition dedicated to fiber optics, Fibre Optics '83, was held in London from 26 through 28 April. It was also the first international conference dedicated to sensor aspects of fiber optics. Although no fiber sensor to date has established that it can economically displace conventional (non-fiber-based) technology, rapid strides are being made, and the field is worthy of close observation.

In environments not conducive to penetration by electrical conductors, fiber sensors have less competition. Whereas fiber optic communication links have clearly established their lower loss advantages over other systems, fiber optic sensors have yet to prove conclusively their superiority. However, two fiber sensors--fiber optic gyros and fiber optic magnetic sensors--clearly can outperform their competition. Because of their sensory capabilities, fiber optics have many applications. They have been used to detect and measure temperature, magnetic and electric fields, elastic waves, velocity, Doppler shift, liquid level, turbidity, color, rotation, pressure, and even the surreptitious tapping of signals from the fiber.

A major problem in using fiber optics as sensors is that any given fiber may be simultaneously responsive to several properties. The undesired responsivity is translated into unwanted noise. A significant part of fiber optic systems research is devoted to suppressing undesired responsivity. The greatest single recent advance in the field was the widespread availability of the optical fiber coupler and directional coupler. With these devices, investigators were largely liberated from the confines of expensive optical tables, half-silvered mirrors, and associated experiment-wrecking vibrations. Thus, as experiments become easier and less costly, more investigators are entering the field.

Detection Sensitivity

Fiber optic sensors are of three basic types: the simple intensity detector, the optical path length change detector used in rotation sensors such as optical gyros (and now commonly known as the Sagnac interferometer), and the Mach Zehnder phase interferometer--the most sensitive, but not universally applicable.

Many existing and proposed fiber optic sensors are based on the use of a Mach-Zehnder interferometer with single-

mode fibers for each of its arms. The parameter to be measured causes (by either direct, indirect, or combined means) in one or more arms of the fiber a phase change that is detected interferometrically with high sensitivity and resolution. Two factors limit ultimate sensitivity. The first is the accuracy with which small changes in phase can be measured and detected by the interferometer itself. This is ultimately limited by shot noise in the optical source. The second factor is the transducer efficiency in converting a small variation, dx, of a parameter, x, under measurement into a corresponding phase change, dϕ. In the simplest implementations, the sensitivity, S, increases with the length of the sensing fiber.

As many parameters are best sensed by transducers employing indirect sensing media, geometric form factors in the overall sensors become highly relevant. E. Ulrich of the Technical Univ. of Hamburg-Harburg (FRG) has derived a formula describing such a sensitivity: $S = a_1 a_2 dx$ [illegible], where V is the transducer volume, A is the cross-sectional area of the fiber, and [illegible] is the optical wavelength. For any given sensor, the material parameters can be combined in the [illegible] constant, f. The utility of the formula can be appreciated even better when one realizes that it is equally applicable to accoustic, electric, magnetic, temperature, and rotational sensors. Thus, if a particularly good sensor is developed for electric field strength measurement, it is reasonable to assume that a similar approach (geometric form factor) can be advantageously applied to hydrophone or other sensor designs.

Temperature Sensors

The use of optical fibers as sensors is often motivated by their capabilities of electrical insulation. Incipient failure of high voltage transformers often may be detected by monitoring temperature at various locations, but electrical potentials can make the task difficult. E. Theocharous of the UK Central Electricity Research Laboratories has successfully used optical fiber sensors for temperature monitoring. His remote temperature sensor is based on the property of ruby glass to exhibit a substantial and reproducible variation in optical absorption with temperature at a given optical wavelength, λ_1, near the ruby absorption band edge. At a nearby wavelength, λ_2, away from the band edge, the ruby absorption is virtually independent of temperature. If such a precharacterized ruby crystal is inserted at a point along the fiber, the total attenuation at λ_1 between two points A and B just before and just after the ruby (and its joints to the fiber) is the sum of contributions due to fiber attenuation, joint losses, and ruby loss.

While the total attenuation at λ_1 is temperature dependent, the total attenuation at λ_2 is virtually temperature insensitive. In a manner similar to that used in radio frequency reflectometer measurements, a short optical pulse at λ_1 is made to propagate down the cable, and a portion of the signal is reflected (backscattered) from both points A and B. The ratio of the intensities of the backscattered light is a measure of the signal attenuation in propagating from A to B and back to A. Similarly, a short pulse at λ_2 experiences temperature independent attenuation, and the two attenuation measurements are then correlated with the ruby temperature. Theocharous inserts such ruby crystals along the fiber at separations. He shows that the ratio of the attenuation between A and B for λ_1 to the attenuation for λ_2 is equal to the square of the ratio of the transmission at λ_1 for the nth ruby plate at λ_1 to its transmission at λ_2. As transmission at λ_2 is temperature independent, transmission at λ_1 can be determined and the temperature of the nth ruby plate uniquely determined. The joint for which the value of temperature is required is selected by a timing gate.

Madame Prof. A.M. Scheggi (Instituto di Ricerca Sulle Onde Elettromagnetiche, C.N.R., Italy) described a fiber optic probe thermometer suitable for medical use in hyperthermia treatment. The probe is noted for its simplicity. The final 1 cm of the fiber is stripped of its cladding and replaced by a small, hollow, right circular cylinder of 1.5-mm external diameter. The fiber core is inserted into the open end of the cylinder, the space between the fiber core and cylinder interior filled with oil, and the cylinder sealed to the fiber. The optical pulse reflected from the probe is a function of temperature. Different oils can be used in the probe to measure different temperature ranges. A sensitivity of 0.1°C has been achieved. In the 37 to 41°C range of the human body, response time is typically 5 seconds. In other temperature ranges, response time can be as long as 20 seconds, depending on the properties of the oil used.

Other fiber optic thermometers discussed included those using bire-

fringent filters and Fabry-Perot cavities. Noise induced by mechanical vibrations can be a rather severe problem with the latter.

Magnetic Sensors

The use of fiber optics as magnetic sensors represents an area of great potential--not so much because of any inherent advantage of the fiber approach, but because of the limitations of other techniques. At room temperature, fiber optic magnetic sensors are predicted to exhibit sensitivities of 10^{-13} Gauss (approaching those of the cryogenic superconducting quantum interference devices), but the performance of the best devices today is several orders of magnitude removed from the projections. Not only are the projected sensitivities exceptionally good, but a 60 to 70 dB dynamic range and directional capability are plausible. If the predictions are realized, fiber-optic-based magnetic gradiometry should also be possible.

Although both polarization sensors and interferometers have been used to sense magnetic fields by fiber optics, most new work uses the interferometer to overcome noise problems associated with polarization control. R. Jones and colleagues (Standard Telecommunications Laboratories Ltd. and Univ. of Surrey, UK) have made notable contributions to magnetic field sensors based on modifications to Mach-Zehnder interferometry. In a conventional configuration, light from each of the arms of the interferometer is combined in a coupler or beam splitter, and the resultant signal is detected by a single photodiode. As beam combination is a polarization sensitive process, any unwanted polarization fluctuations introduced into an interferometer arm translate into unwanted system noise. Similarly, any intensity fluctuations in the source or detectivity fluctuations in the photodiode also translate into background noise.

When Jones eliminated the beam coupler, there was virtually no polarization-induced noise. Instead, light from each of the two interferometer arms was effectively recombined by placing the output ends adjacent and parallel. Thus, the outputs act as point sources and create an interference fringe pattern, which is monitored by a 128-element photodiode array configured as a charge coupled device (CCD). The magnetic-field-induced changes in optical phase alter the position of the fringes, while the unwanted polarization-induced and other noises alter the contrast ratio and intensity of the fringe pattern. A microcomputer was used to normalize all fringe patterns to unity contrast ratio and intensity. Because more than one fringe is monitored, the sensitivity of the detector is independent of the zero-field fringe pattern, and no active feedback compensation to retain a quadrature relationship between the interferometer arms is required. The approach not only is simpler than most, but it also systematically eliminates major sources of noise. An impressive sensitivity of 2×10^{-4} radians/tesla meter was achieved by bonding one interferometer arm to 30 mm of Vitrovac 4040 magnetostrictive metallic glass ribbon. The efficacy of the metallic glass derives from a bending effect resulting from a physical movement of the magnetic domain walls through the ribbon during magnetization. The movement strains the fiber and induces the detectable optical phase shift.

Fiber optic magnetic field sensors used to measure high currents in high voltage environments are described in FSN 37-1:30 (1983).

Fiber Optic Gyros

Six papers were on fiber optic gyroscopes; only one, by I. Giles et al. of University College London represented a marked departure in design (FSN 37-4: 133-138[1983]). H. Lefevre and colleagues (Thompson-CSF and Ballistics and Aerodynamics Research Laboratories, France) described results on a one-axis, integrated circuit, fiber optics gyro. The diode laser, couplers, polarizer, and photodetector were all on a common GaAs semiconductor chip; the fiber rotation sensing coil and piezoelectric transducer (PZT) modulator were external. (Future integrated circuits may include the modulator.) The brass board experimental apparatus was displayed in the exhibition hall. A random walk of 15 degrees/hr was demonstrated; considerably more research is needed to eliminate problems with unstable bias offset, losses, and polarization control before useful overall characteristics are obtained.

Problems Requiring Further Research

Although the integration of couplers (replacing beam splitters) and other packaging improvements have significantly improved system noise figures (especially critical in sensitive interferometer-based sensors), diode laser noise remains a problem. Single-mode diode lasers with pigtail fibers attached are now remarkably free of vibration-induced noise and greatly simplify experimentation. Their remain-

ing noise properties are of three basic types: intensity (AM), phase (PM), and coherence time (FM). All are strongly sensitive to light backscattered into the laser cavity. The most promising approach to reducing phase noise appears to be use of a feedback-compensating diode current derived from an external frequency discriminator. New quantum well and modulation-doped structures may improve intensity noise and coherence time. Of particular interest is the transverse striped multiple quantum well device; while not yet made, the device should be particularly stable.

[illegible]

MATERIAL SCIENCES

FIBER COMPOSITE MATERIALS IN THE UK: NATIONAL PHYSICAL LABORATORY AND UNIV. OF LIVERPOOL

This is the fourth in a series of articles reporting research activities on fiber composite materials in the UK. Research at the National Physical Laboratory and the Univ. of Liverpool is highlighted this month.

National Physical Laboratory

The National Physical Laboratory (NPL) is the UK's national standards laboratory. Founded in 1900, it is in Teddington, Middlesex (TW11 OLW). Over the years, the work at the laboratory has varied considerably in response to the changing technological needs of the country, but the broad objectives in standards, metrology, and industrial support have remained the same. Today, NPL is one of the six research establishments of the Department of Industry and employs about 900 people; over 600 hold professional qualifications. There are scientific divisions in electrical science, information technology and computing, materials applications, mechanical and optical metrology, quantum metrology, and radiation science and acoustics. I visited the Division of Materials Applications, where the research interests include polymeric and composite materials, materials performance at high temperature, materials processing technology, and interface related properties.

The Polymers and Composites Group has a staff of 20 with expertise in physics, chemistry, and applied mechanics. The work includes projects funded by specific industrial customers, projects of medium-term interest to a range of industries, and work of a more fundamental nature that supports standards and specification activities and generally improves the base of knowledge of the materials. Current research includes rubber, polymeric foam, fiber-reinforced thermosets, engineering thermoplastics, and short fiber reinforced thermoplastics. The following projects are in the core program: (1) engineering design methods and data, (2) long-term engineering properties of glass reinforced plastics, (3) long-term fracture of thermoplastics, (4) influence of processing on polymer structure and performance, and (5) quality assessment of injection molded reinforced thermoplastics.

The research in engineering design is best exemplified by the influential books of A.F. Johnson (1978) and F.J. Lockett (1982). Both works teach design engineers to take full advantage of the structural properties of plastics and composites and to optimize product design.

To assess the long-term performance of composites, J. Aveston, J.M. Silwood, L.N. McCartney, and A. Kelly have systematically examined stress corrosion of fiber bundles and glass reinforced plastics in water and dilute sulphuric acid. The work of Kelly and McCartney is concerned with bundles of fibers loaded from their ends and immersed in a corrosive environment. The time to failure of the bundles is extremely sensitive to the value of the applied load. To account for this behavior, the researchers used: (1) the empirically established relation between rate of crack growth and stress intensity factor found for many brittle materials, and (2) a two-parameter Weibull distribution for the initial lengths of the cracks in the fibers. The theory explains the time to failure of the bundle and the rate of failure of individual filaments during stress corrosion. Aveston, Kelly, and Silwood have extended their theory to examine systematically the long-term strength behavior of E-glass, Cemfil glass, T-300 carbon and Kevlar-49 fibers, and the impregnated strands of the fibers under static and fatigue loads. More recently, Aveston and Silwood turned their attention to the long-term strength of glass reinforced plastics in dilute sulphuric acid. Two reinforcements were used: conventional E-glass and Cemfil, which is an alkali-resistant glass developed for reinforcing cement. E-glass reinforced polyester rapidly falls in strength and

fails by brittle crack growth. It makes no difference whether the loading is static or fatigue. Also, presoaking in acid in the unstressed state has little effect on subsequent strength. Cemfil-based composites, on the other hand, are insensitive to dilute acids, falling in strength by about 1% per decade of time. Aveston and Silwood have also shown that fatigue failure in acid is simply a special case of stress corrosion, and there is no additional degradation as a result of load cycling. They concluded that the long-term strengths of glass fiber composites and stress corrosion can be safely predicted by extrapolation of medium-term tests plotted in the form of log strength versus log time.

University of Liverpool

The Department of Metallurgy and Materials Science at Liverpool Univ. has a very high concentration of materials research (see ESN 37-4:146-148 [1983]. The department has nine faculty members, 19 research fellows and associates, and 24 graduate students. Forty-nine research projects in metal and polymeric materials are in progress. The composite materials research program in the department is chiefly concerned with fiber reinforced plastics. Prof. Derek Hull leads the composite research effort. There are four major areas of activity: failure of filament-wound tubes, energy absorbing composite materials, reinforced reaction injection molding, and injection molding of thermosetting composite materials. Three members of the academic staff and 20 research associates and students are participating in the work. The programs are supported by the UK's Science and Engineering Research Council (SERC) and industrial companies, including Pilkington Brothers, Ford Motor Co., British Petroleum, ICI, Freeman Chemical, and Scott-Bader.

Research interest in filament wound pipes at Liverpool Univ. was first stimulated in 1973; it seemed possible to use glass reinforced plastic (GRP) pipes to replace conventional steel and concrete pipes for effluent disposal and water distribution. GRP pipes can be made in many ways, including wet lay-up with chopped-strand mat fibers, centrifugal casting, and filament winding.

Initial studies identified some factors limiting the use of GRP. One problem, for example, is the weepage of fluids at pressures less than 20% of the burst pressure. This factor--along with considerations such as safety to cover fatigue, temperature, and environmental effects--means that GRP pipes have to be used at pressures much lower than those predicted from the strength of reinforcing fibers. The research programs at Liverpool Univ. examine these problems in glass/polyester pipes. An analytical program was developed to determine the ideal winding angle of fibers in order to minimize the stress transverse to the fiber direction, which is the cause of transverse cracking and weepage. Experimentally, it was observed that transverse cracks nucleate preferentially in the region between closely spaced fibers at, or very close to, the fiber-matrix interface. The occurrence of the matrix cracking is attributed to the high strain concentration in the matrix material, which has an elastic modulus much smaller than that of the fiber.

To alleviate the problem of transverse cracking, Hull and his coworkers have tried two approaches: increasing the strain to failure ratio of the resin and reducing the strain concentration effect. To examine the first problem, they made a large number of tests on a series of resins "flexibilized" by adding increasing amounts of a second resin. The results show that as the modulus decreases, the strain to failure ratio increases. Thus, an improvement in transverse failure strain can be achieved. However, there are limits to the improvements that can be achieved by flexibilizing, because the stiffness properties of the bulk composite are affected adversely.

To test the second problem, a major program has been carried out using fibers that are first coated with a polymer with mechanical properties different from those of the matrix resin. It is necessary to ensure that the polymer interlayer forms a chemical bond with the silane coupling agent on the glass fibers and with the reactive groups in the matrix resin. Significant improvements in transverse strain to failure ratio have been achieved with some polymer interlayers. The interlayer presumably is able to minimize the discontinuity in strain distribution between the fiber and matrix, thus reducing the strain concentration effect.

As part of the filament-wound-pipe program, a multiaxial test program was started a year ago. The machine was built at North East London Polytechnic, and the microprocessor controls were developed at Liverpool. The machine can test tubes in combined loadings, with compression-torsion, axial tension and compression, and internal pressure. One of the main problems in the test is to define and then achieve the loading path. Both load control (the ratio of

different loads--e.g., axial and hoop loads--is constant throughout the test) and strain control tests have to be performed. Another complication in the multiaxial tests is that failure may depend on the path of loadings. The problem is particularly important when the laminate exhibits viscoelastic properties.

Stress corrosion fracture is also being studied for filament wound pipes under the combined influence of an acidic environment and a stress parallel to the fibers. One of the specimen geometries in the tests uses a short section of pipe under diametrical compression. Maximum tensile stresses are generated on the inside of the pipe section near the compression platens, and in such regions stress corrosion occurs. Another type of specimen design is based on the fracture mechanics approach; a flat unidirectional sheet is used with a crack growing normal to the fiber directions under an acidic environment.

Prof. Hull's program in energy absorbing composite materials is concerned with a composite material's capability of absorbing energy in its bulk rather than at the tip of a crack--as in the case of transverse cracking described above. The research began because of its applications in the automobile industry; the safety of passengers during a high-speed crash depends on the progressive and controlled collapse of the structure frame of the car. The work started about 4 years ago and is being done by a multidisciplinary team of chemists, physicists, mechanical engineers, and materials scientists. There is close collaboration with industrial partners--British Petroleum, Ford Motor Company, and Pilkington Brothers--and the Polymer Engineering Directorate of the SERC. One of the main objectives of the work is to explore the possibility of designing and fabricating composite materials which retain their high strength and stiffness and, in a controlled way, absorb large amounts of energy by the various microfracture processes. After discussions with the Motor Industry Research Association, the researchers decided to base the initial work on the collapse of tubes tested in axial compression. With the help of several industrial companies, Liverpool Univ. has developed facilities for fabricating 50- to 100-mm-diameter tubes by a number of significantly different methods. Each approach offers the possibility of changing in a controlled way the fibers, the resins, and the arrangement of the fibers so the effects can be investigated systematically.

Two high-speed testing machines are being used. A servo-hydraulic machine operates at speeds up to 4 m/s. It was designed and built at Cranfield Institute of Technology and has a maximum crushing load of 200 kN. A catapult impact machine, built by Mand Testing Machines, has a maximum speed at impact of 15 m/s (35 mph); it is used to evaluate components under realistic crash conditions. The component to be tested is mounted on a 290-kg sled in the machine and is driven along an 8-m track by parallel Bungee cords; an initial acceleration of 3 g is produced. The track is mounted in a rigid box-girder frame and terminated at the impact end by a thick steel target plate. On release of the trigger, the sled and the track and frame move toward each other at velocities determined by their relative masses. Impact forces are measured by four load cells, which support the target plate. Data are stored digitally and processed by an Apple II computer to produce acceleration and velocity profiles, and energy absorbed versus crush distance diagrams.

The first group of composite tubes tested in the program failed in a brittle manner and with no controlled collapse. Such behavior is, of course, totally unacceptable for automotive applications. A possible solution is to design into the tube a large number of weak sites, which will produce local failure rather than catastrophic fracture. During the work, a much more elegant and simple solution was found. One end of the composite tube was chamfered so that the first failure occurred by crushing the material at the chamfer. Because the effective cross section of the tube is less at the chamfer than for the remainder of the tube, the initial crushing force is less than the peak force for an unchamfered tube. It has been found that once the crushing process is started at one end of the tube, it can lead to progressive crushing, which eliminates the peak force that leads to catastrophic fracture. The force-displacement curve has a characteristic shape; there are many serrations due to the progressive microfracturing of the material in the crush zone. The overall shape of the curve, with an approximately constant crushing force over the full length of the tube and no initial peak, is close to ideal for optimum deceleration.

The energy absorbed per unit mass, W_s, of the material crushed is one of the parameters used to compare the

energy absorbing properties of a material. Typical values of W_s are 25 to 30 J/g for mild steel, 10 to 16 J/g for aluminum, and 15 to 25 J/g for polycarbonate. The composite tubes have demonstrated 40 to 60 J/g. Values of W_s up to 120 J/g have been achieved with some fiber-resin systems. Tests also have shown that W_s is relatively insensitive to crushing speeds up to 35 mph. It is exciting to be able to achieve such a high level of energy absorption by improving design and fabrication. Since the material is used on a structural component, the fibers must be carbon, glass, or Kevlar, according to Hull. In addition, to achieve optimum use of the high strength and stiffness of the fibers, they must be aligned in predetermined directions. A detailed microscopic analysis has shown that at least 10 different energy absorbing mechanisms have occurred in the tube failure process. However, in spite of work worldwide on the microfracture of composite materials, there is still no sound physical understanding of the processes involved in the crushing and the high energy absorption capability of the tube material (Hull, 1983).

Other research in the department includes Dr. J.B. Shortall's work with mechanical properties, particularly impact and creep resistance of reinforced reaction injection molding polyurethane elastomers. Components are made by mixing two low viscosity liquids (usually a di-isocyanate and a polynol) containing chopped fibers and injecting them into a closed mold at relatively low pressure. Polymerization occurs rapidly in the mold to form the final urethane-based product. Dr. A.G. Gibson's work is concerned with structure-property relationships of glass reinforced thermosetting resin systems using injection molding.

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T.-W. Chou

INCO MAP CONFERENCE: FRONTIERS OF HIGH TEMPERATURE MATERIALS II

Frontiers of High Temperature Materials II, an international conference, dealt with the strength, thermal stability, and corrosion properties of International Nickel Company alloys MA754, 956, and 6000. The conference was held in London from 22 through 25 May 1983, and was sponsored by Inco Alloy Products Company; the first conference was held in New York in 1981.

Conference II dealt with the latest properties and uses of oxide dispersion strengthened (ODS) superalloys made by a proprietary Inco process of mechanical alloying (MA). The process is a dry, high-energy ball grinding method of producing a cold-welded uniform dispersion of highly refractory oxide particles in an ultrafine metallic superalloy matrix powder microstructure. The powder is subsequently canned and consolidated either as bar or sheet material by hot extrusion and rolling. The material is mainly used in advanced aircraft engine components.

The technical program included the following sessions: Background of Mechanical Alloying, Basic and Engineering Studies, Aircraft and Vehicular Gas Turbines, Industrial Gas Turbines, and Industrial Processes. Nineteen papers were presented by scientists from the US, the UK, Switzerland, West Germany, and Canada, including seven papers by Inco employees from the US and the UK. The audience included 101 registrants from these five countries, plus Belgium, France, Israel, Japan, Korea, Norway, Sweden, and the Netherlands.

Inco MAP Background

J.S. Benjamin, General Manager of Inco MAP, opened the conference. Inco MAP, Inco Mechanically Alloyed Products, was organized in 1980 to coordinate the joint US-UK development, production, and marketing of the new MA ODS products. Three Inco companies are involved: Huntington Alloys, Inc. (West Virginia 25720); Wiggin Alloys Ltd. (Hereford HR4 9SL, England); and Doncasters Monk Bridge Ltd. (Leeds LS1 1PE, England).

Benjamin pointed out that the current MA products were developed for the strength, thermal stability, and corrosion resistance needed at increased temperatures to improve the thermodynamic efficiency of turbomachinery and power generation. The products were used in furnaces and chemical processing equipment. Emphasis was being given to three materials: nickel-base Inconel MA 754 for forged turbine vanes, fuel nozzles, and spun rings; iron-base

Incoloy MA 956 for uses such as turbine blades, tubes, thin rings, swirlers, and combustion chambers; and nickel-base Inconel MA 6000 for advanced turbine blades.

Exceptional facilities are available to Inco MAP in the US and UK: at Huntington Alloys, five attritors giving 15 tons of mill product capacity and a bar rolling mill for MA 754 alloy; at Wiggin Alloys, a 1-ton powder-batch ball mill, a 5,000-ton extrusion press, and a 3.7-m heat treating furnace capable of operating at 1,370°C; and at Doncasters Monk Bridge, a 250-ton hydraulic isothermal press that can operate at 1,100°C for MA forgings. The press is also capable of positional control to 8 microns over strain rates from 0.0003/s to 0.2/s. The total Inco MAP mill product capacity was 15 tons per year in 1980 and is projected to increase from 55 tons per year in 1983 to 200 tons per year in 1986. In 1982, $3,200,000 in material sales were made at prices ranging generally from $50 to $150 per pound.

G.A.J. Hack (Wiggin Alloys Ltd., Inco MAP) presented the paper "Fundamentals of Mechanical Alloying." The γ' (Ni_3Al) strengthening of conventional nickel-base superalloys disappears at about 1,000°C because the γ' particles coarsen and dissolve. Yttria oxide (Y_2O_3) particles have a greater thermodynamic stability; however, the MA process had to be developed by Benjamin and colleagues to disperse very fine particles--say, less than 30 nm in size--within a sufficiently refined superalloy microstructure to be effective at the higher temperatures where γ' strengthening normally decreased.

Conventional powder particle sizes are fed into attritors, which produce smaller particles with an ultrafine deformation microstructure within them and cold-welds the particles together. The raw material powders for MA 6000 are a 10-component mixture of type 123 Inco nickel; chromium; molybdenum; tungsten; tantalum; Ni-Al-Ti, Ni-Al, Ni-B, and Ni-Zr masteralloys; and yttria. Contamination within the attritors is not a problem because the steel balls used for grinding develop a superalloy coating on their surfaces. Thermomechanical processing by extrusion of the canned MA powder and subsequent hot rolling does more than produce a sound product of elongated grains; by control within narrow limits, a more beneficial coarse elongated grain structure--say, with an aspect ratio of 8--is produced by a secondary recrystallization heat treatment. Interdiffusion occurs during heat-up for the extrusion process, which is less expensive than hot isostatic pressing. Further details are given in "Inco's New ODS Superalloys for the Eighties," *Metal Powder Report*, 38 (1983), 32-35.

Basic and Engineering Studies

R.C. Benn (Inco Alloy Products Company Research Center, Sterling Forest, NY 10901) presented "Machining of MA Products." A low-speed rigid apparatus without backlash is required for machining; carbide tools are preferred. To minimize work hardening, the tools should be designed for cutting the material rather than shearing it. Alloy MA 956 is body centered cubic and shows a ductile-to-brittle transistion in the temperature range of 40 to 70°C. Benn described Inco's experience with milling, drilling, broaching, tapping, threading, reaming, planing, cutting, sawing, grinding, and electrodischarge and electrochemical machining. The general machining characteristics can be matched with other established materials as follows: MA 6000, which can only be cut with an abrasive wheel, is similar to Udimet 700; MA 754 is easier to machine than Inconel 718 but not so easy as type 410 stainless steel; and MA 956 is comparable to 410 stainless steel. The MA alloys machine better than would be indicated by the hardness or strength level correlations frequently used as an index of machinability. The following machined examples were shown: for MA 754, a turbine vane airfoil and assembly for the General Electric F404 and F101 engines and an industrial gas turbine compressor blade; for MA 956, a riveted combustor assembly, burner nozzles, locking nuts, and fuel nozzle shrouds; and for MA 6000, advanced high pressure turbine blades for the Garrett Airesearch TFE-731 turbofan engine.

R. Petkovic-Luton presented "Microstructural Aspects of Creep in ODS Alloys," co-authored with D.J. Srolovitz and M.J. Luton (Exxon Research and Engineering Company). The researchers studied Incoloy MA 956 material supplied by Huntington Alloys Inc. in the form of a coarse elongated grain structure and in a fine equiaxed grain structure. The ferritic grain structure was coarse enough that single crystals could be cut from the bar material and tested individually. Within the individual crystals, a mean particle size of 24.5 nm and spacing of 109 nm were determined by transmission electron microscopy of thinned foils. From the measurements and dislocation observations, it was determined that the threshold stress for dislocation creep was lower than the computed Orowan stress for dislocations

being held up by bowing between the incoherent particles. Furthermore, such bowed loops were not observed. Dislocations intersected the interfaces of the dispersed phase particles; a dislocation delocalized-core-type calculation for the observations gave a threshold stress in agreement with the single crystal results.

The fine grained polycrystal material gave creep rates 100,000 times greater than for single crystal specimens when tested at 1,050 to 1,100°C and at a relatively low stress of 35 MPa. A creep rate about 10 times greater, about 0.01/s, was estimated at 90 MPa. The polycrystal results were attributed to diffusion-assisted grain boundary sliding, which seemed to be confirmed by tests on bicrystal specimens also cut from the large grained material. An interesting metallographic observation, taken as evidence of a role for diffusion, was that failed inclined boundary regions of the bicrystal specimens showed the boundaries were denuded of dispersoids. The researchers also observed yttria particles alone and mixed particles of alumina (Al_2O_3) and yttria. The indication is that the mixed particles grow at high temperature by the addition of aluminum and oxygen, not by the dissolution of small particles of yttria. J.K. Tien (Henry Krumb School of Mines, Columbia Univ.) reported that his students had observed a normal type of Ostwald ripening behavior for the change in size of particles and disappearance of small ones for such material tested in the temperature interval of 1,050 to 1,300°C.

E. Grundy (Doncasters Monk Bridge Ltd. [DMBL], Inco MAP) presented "Forging and Fabrication of ODS Alloys," co-authored with W.H. Patton, C.J. Precious, and D. Pinder. A major effort has been to convert mill product MA materials into forged, fabricated, and finished products while maintaining the original properties of the alloys. Examples were shown of MA 754 vanes and shrouded blades with drilled cooling passages, giving a rupture life of 100 hours at 112 MPa at 1,100°C. Forged fuel nozzles and spun rings for seals and combustors were shown for MA 754. Isothermally forged MA 6000 rotor blades were shown for advanced gas turbines without blade cooling. The forging parameters are controlled with regard to the employment of subsequent recrystallization treatment by zone annealing. Cracking during forging is prevented by the materials having been canned. Continuous rings of MA 956 have been forged, rolled, and recrystallized. As with MA 754, MA 956 fuel nozzles have been forged and recrystallized to give elongated shape-following grain structures that can withstand aggressive oxidation and sulphidation atmospheres, say, at 1,100 and 917°C, respectively. It is hoped that MA 956 will have engineering applications in the oil, petrochemical, and power generation industries. A thin, surface adherent alumina film is applied for enhanced resistance to corrosion. New applications are swirler vanes for power station boilers, tubes for fluidized beds, and sheets for nuclear power uses.

Another paper in the session was by T.J. Kelly (Inco Alloy Products Research Center, Sterling Forest). He discussed vacuum and commercial brazing as well as welding by laser, electron beam, gas tungsten-arc, gas metal-arc, and shielded metal-arc methods--particularly for MA 956 uses where its excellent corrosion resistance are of primary concern. T.A. Hughes presented "Some Aspects of the High Temperature Embittlement of MA 956," co-authored with T. Hirst (Houldsworth School of Applied Science, Univ. of Leeds). Fractographic observations were made in the study, which was supported by the Department of Industry. J.M. Davidson followed with "Ductile-Brittle Transition Behavior of MA 956." The MA 956 brittleness transition, characteristic of ferritic alloys, normally occurs near room temperature. As expected, the transition was suppressed by reducing the grain size within the powder product. B. Jahnke and A.R. Nicoll (Brown, Boveri and Cie AG [BBC], Heidelberg, FRG) presented "Joining and Coating of ODS Superalloys."

Aircraft and Vehicular Gas Turbines

R.L. Dreshfield (NASA Lewis Research Center) presented "Progress Toward Determining the Potential of ODS Alloys for Gas Turbine Applications," co-authored with G.S. Hoppin (Garrett Turbine Engine Company) and K.D. Sheffler (Pratt and Whitney Aircraft). NASA has supported two projects involving MA materials: the development of improved combustor liners using MA 956 by Pratt and Whitney, and the development of higher temperature turbine blades using MA 6000 by Garrett. A 150°C temperature advantage has been gained with MA 956 with brazed and riveted combustor louver panels for the 2037 engine. Experimental MA 6000 high-pressure uncooled turbine blades have been made for the Garrett TFE 731 engine, giving an 85°C temperature advantage over any directionally solidified turbine alloys. The materials might be used in NASA's Space Shuttle. A major objective is to lower

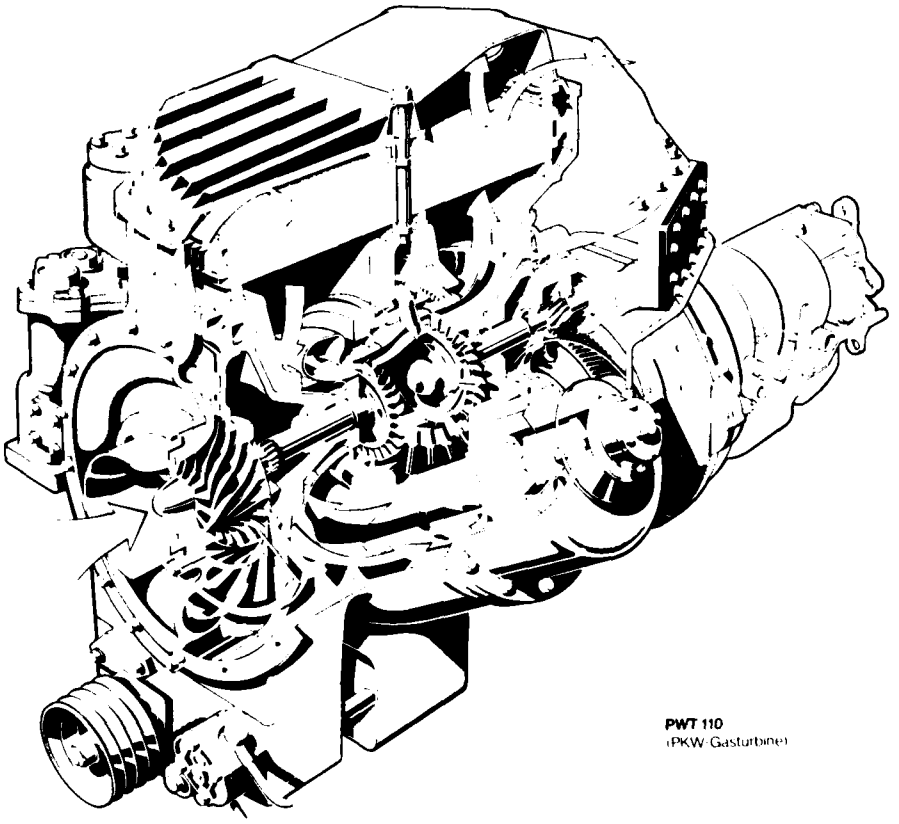


Figure 1. The Daimler-Benz experimental vehicular gas turbine.

the price of materials from, say, $50 per pound for MA 754 and $150 per pound for MA 6000.

"Incoloy MA 956 for Vehicular Turbine Applications" was presented by E. Tank (Daimler-Benz AG). Figure 1 shows the PWT 110 engine, which has been under development for several years. The gas temperature in the combustor reaches 1,250°C. The two monolithic turbine wheels are made of hot-pressed silicon nitride. MA 956 is used for three stationary parts: a compressor turbine nozzle manufactured from 26 machined parts involving electron beam welds and capable of withstanding up to 1,300°C; a turbine inlet plenum characteristic of small engines; and an interdiffusor exterior cone positioned between the compressor and power turbines. There could be other uses for small, thin-walled MA 956 tubes and larger forged MA 956 material with properties equivalent to those reported for sheets. It was estimated that a price reduction of a factor of 10 would be required for MA 956 to compete with future ceramic materials.

W. Crawford (General Electric Company, MA) delivered "ODS Materials in Advanced Gas Turbines-MA 754 Vanes." Military gas turbines have advanced from steel and titanium parts to forged MA materials, which are used now. MA 754 vanes are in the F404 engines powering the F20 aircraft tested by the US Navy. The engines are to be used by the Australian and Canadian air forces. Electrodischarge machining is used for internal cooling holes because turbine inlet temperatures are extremely high. Laser drilling of such holes is being investigated. A peak temperature of 1,100°C is reached at the vane surface. The life of the vanes increases by 10 times with the uncoated MA 754 material, but the cost is two to three times greater than cast materials such as Martin Marietta's MAR M509 alloy.

R.G. Wing (Rolls-Royce Ltd., UK) presented "The Development of ODS MA 6000 for Use in Small Gas Turbine Engines." A laboratory test program was set up to determine the suitability of the alloy for small solid blades, say, 1 in. long. MA 6000 has a definite

increase-in-temperature advantage over directionally solidified and single crystal materials. However, the notched low cycle fatigue strength of MA 6000 falls below that of directionally solidified MAR M002. A protective coating for oxidation and corrosion resistance is needed--perhaps a cobalt-modified aluminide coating. For the near future, single crystal material will be used because it is less expensive through multiple casting possibilities, but MA 6000 may be used eventually.

Industrial Gas Turbines

"Hot Corrosion Testing of ODS Nickel-Base Alloys" was discussed by P. Huber (Sulzer Brothers Ltd., UK). Temperatures were 850 and 950°C; cycling oxidation studies were done at 1,100°C. The gas velocity was varied. Coatings are necessary for protection against corrosion of stationary gas turbines. K.P. Willett (Westinghouse Canada Inc.) presented "Incoloy MA 956 Diffusers for Industrial Gas Turbines." The alloy has been successfully substituted in a combustor system baffle plate assembly of a W191, 17.5 MW turbine. Electron beam welding was chosen for fabricating the assembly. Operating at temperatures up to 1,100°C, the unit was still functioning after 2,200 hours, compared with 500 hours for the previous alloy system. A combustion chamber design employing MA 956 has been developed, and Westinghouse Canada hopes to proceed with it if the Canadian government supports the project.

R.F. Singer (BBC Research Center, Baden) presented "Creep Rupture Properties of Inconel MA 6000," co-authored with R.C. Benn and S.K. Kang (Inco Alloy Products Company Research Center). The creep properties of MA 754 and MA 6000 were compared with those well established for IN 738 and IN 939 as reference materials (see R.W. Armstrong, "High Temperature Alloys for Gas Turbines - 1982," ESN 37-1:21-24 [1983]). The MA ODS materials showed much better long-time creep rupture properties, which are important for industrial gas turbine applications. The results agree with others obtained at Sulzer Brothers Ltd. No major changes in microstructure seemed to have occurred during creep. The strengthening of γ' is needed in the intermediate 900 to 1,000°C temperature range, as shown by Wing. Additivity of the strengthening within the ODS material is extremely important. The γ' particle diameters increase somewhat as creep proceeds, but no weakening occurs--in agreement with results described by Petkovic-Luton and colleagues. Elongated grain structures gave improved creep properties because the grain boundary sliding deformation observed in grain structures with small, near-unity aspect ratios was absent--also agreeing with the Petkovic-Luton work. An interesting consideration for MA 6000 was that its otherwise desired <100> texture seemed to place it in a relatively weakened condition when compared with untextured material on a Larson-Miller basis. During the discussion that followed his presentation, Singer estimated that the long-time strength advantage of MA 6000 contributed perhaps a 25-year advance in alloy development; however, the corrosion resistance of the material and the transverse ductility needed improvement.

Industrial Processes

One of Inco MAP's major objectives is to use MA materials in industrial power generating equipment, including nuclear plants, and in petrochemical plants. D.M. MacDonald (Central Electricity Generating Board, UK) presented "Performance of Incoloy MA 956 in Laboratory Corrosion Tests and in the Operating Environments of Fossil Fuelled Boilers." No blade or rim distortion or corrosion was observed for stabilizer units in burners at 1,100°C. The oxide layer on the alloy was exposed to sodium sulphate and vanadyl sulphate, representing the aggressive atmospheres of the burner chambers. The results showed that the alloy is susceptible to localized attack and penetration. Various elements were identified by electron probe microanalysis. Further work is needed to quantify the effects.

R.H. Kane (Inco Alloy Products Company Research Center) followed with "Some Aspects of High Temperature Corrosion of ODS Alloys." The corrosion studies have involved cyclic oxidation at 900 to 1,200°C with an air-5% water atmosphere, fuel corrosion in a burner rig atmosphere, combined sulphidation and oxidation attack simulated for coal gasification environments, combined carburization and oxidation with hydrogen and methane-water mixtures, and nitridation such as that occurring in metallurgical sintering furnaces. Many materials were compared; MA 956 fared best among the MA alloys. Further improvements should result from mechanical alloying development work intended to confer special corrosion-resistant properties on the materials. Research has already improved the mechanical properties.

The final paper, "Application of Incoloy MA 956 in Combined Cycle Coal Gasification Environments," was pre-

sented by D.M. Lloyd (UK National Coal Board). The sulphidation resistance of MA 956 has indicated that the alloy could be a candidate for pressurized fluidized bed combustion. Again, it was emphasized that using materials that can withstand higher temperatures offers the advantage of higher thermal efficiency; for example, 45% efficiency might be achievable instead of the current 35 to 38.5%. The gasifier, raw gas waste heat boilers, gas cleaning units, and gas turbines are expensive, critical components of the systems. The gas environments are extremely hostile even to pre-oxidized alloys. MA 956 shows promise for uses such as instrument probes, raw gas heaters, and hot gas filtration. Future work should be devoted to procedures for forming a beneficial alumina scale on the alloy.

Summary

Inco MAP has demonstrated that its MA alloys have significantly improved creep properties at high temperatures--particularly for advanced engineering gas turbines that run for long periods of time. The results are confirmed by current and potential users. The materials are expensive, but their use is expected to increase significantly. The company wants to expand to other markets, such as petrochemical processing, in which corrosion resistance and reduced cost of the materials are critical considerations.

A.W. Armstrong

OCEAN SCIENCES

THE LIÈGE COLLOQUIUM ON OCEAN HYDRODYNAMICS

The Fifteenth International Liège Colloquium on Ocean Hydrodynamics was convened by Prof. Jacques C.J. Nihoul at the Sart Tilman Campus of the Univ. of Liège, Belgium, on 2 May 1983. The topic of the 5-day conference was "Remote Sensing of Shelf Seas Hydrodynamics." Twenty-five papers were presented by participants representing institutions in Belgium, Canada, the People's Republic of China, the UK, France, India, Italy, Japan, Norway, Spain, and the US.

In his opening remarks, Nihoul (Univ. of Liège) discussed the potential of remote sensing for both understanding and modeling processes that take place in shallow seas. He reviewed applications of satellite, airborne, and land-based remote sensors, with special emphasis on the success of shore radar in providing useful data on offshore surface currents and wave heights. Nihoul concluded that remote sensing has proved valuable in calibrating models but as yet cannot provide the necessary input parameters and boundary conditions for operating models.

Invited Papers

Various aspects of the conference theme were highlighted by four invited speakers: Drs. J.F.R. Gower (Institute of Ocean Sciences, Sidney, British Columbia, Canada), R.D. Pingree (Institute of Oceanographic Sciences, UK), T. Maruyasu (Science Univ. of Tokyo), and J. Carstens (Norwegian Hydrodynamic Laboratories). Gower was an articulate representative of the satellite fraternity. He considered several aspects of remote sensing imagery, including radar, thermal mapping, and multispectral color sensors. The coastal zone color scanner (CZCS) has proved to be one of the most useful sensors for modelers, particularly for monitoring plankton blooms and the resultant indications of water motion. The use of the chlorophyll fluorescence at 685 nm helps to separate chlorophyll concentrations from Raleigh scattering effects in the blue-green spectral range. Using examples from the Bay of Biscay and the English Channel, Pingree stressed the interaction between remote sensing and hydrographic measurements. By showing thermal, CZCS, and synthetic aperture radar (SAR) imagery of the area, he demonstrated how the appearance of fronts, internal waves, plankton blooms, and residual currents in remote sensing can influence the type of *in situ* hydrographic measurements required for calibration of hydrodynamic models.

The other two invited speakers were primarily concerned with remotely sensible, coastal hydrodynamic features relevant to pollution transport. Maruyasu and his colleague, T. Nishimura, presented a kinematic analysis of self-propelled vortices and their role in the water mass and biological exchange in the Akashi Strait region of Japan. The analyses were supported by both remote sensing data and large-scale laboratory experiments. Carstens discussed remote sensing imagery of the boundary current along the west coast of Norway. The Norwegian coastal runoff that enters the current, which carries pollutants from the Baltic and North seas, has been modeled in considerable

detail and indicates the presence of cyclonic jets occasionally erupting from the coastal currents. The eddies or meanders, which have been confirmed by satellite photos, contribute substantially to the maximum currents predicted near off-shore oil drilling rigs.

Contributed Papers

The contributed papers covered a broad range of subjects from models of oil slick transport to topographically forced eddies in a rotating tank. The model of surface oil transport produced by Nihoul indicated the importance of the thickness and type of oil in determining its movement. The model specifies in detail the roles of gravity, friction, surface tension, and meteorological parameters in dispersing such pollution. Nihoul also evaluated the capabilities of various optical, thermal, and radar remote sensors for detecting and quantifying oil spills. E. Salusti (Univ. di Roma) discussed SAR and thermal satellite imagery in the Strait of Messina. Salusti's primary concern was the mixing of Atlantic and Levantine water in the strait--an effect caused by strong tidal currents over the shallow sill. He also raised the interesting prospect of energy propagating away from the strait in the form of remotely sensible internal solitary waves (see ESN 36-9:220-221 [1982]).

Remote sensing as an aid in studying Mediterranean dynamics somewhat further west in the Alboran Sea was the subject of a paper by A. Ballester (Instituto de Investigaciones de Pesqueras, Barcelona). He pointed out the relationships of classical hydrographic measurements to synoptic imagery from satellites such as National Oceanographic and Atmospheric Administration (NOAA) 6 and 7, Landsat, Tiros N, and Nimbus A. The relationships can serve as indicators of upwelling, frontal systems, nutrient concentration, and biological productivity. Shouren Lin (Second Institute of Oceanography, Hangchow, People's Republic of China) presented a detailed analysis of his methods for interpreting CZCS satellite imagery of chlorophyll concentration in the sea. To avoid problems with green-blue ratios, Lin has concentrated on mathematically fitting the chlorophyll fluorescence peak at 685 nm. His methods have been quite successful in reconstructing measured phytoplankton populations based on Gaussian fitting of CZCS spectral measurements.

The work presented by P. Piau (Institut Francais du Pétrole) emphasized that remote sensing does not necessarily involve spaceborne systems. Using land-based, high-frequency radar, Piau and Blanchet have studied surface currents and horizontal turbulence up to 150 km off the coast of Brittany. Their radar measurements near Ushant Island show excellent agreement with *in situ* current data.

S. Djenidi (Univ. of Liège) discussed the application of NOAA and Tiros infrared imagery to the investigation of hydrodynamics in the western Mediterranean Sea. Because absolute sea temperatures measured from space are of limited reliability, Djenidi has concentrated on using thermal gradients to reveal fronts, eddies, upwelling, and currents in the area. The usefulness of satellite imagery was highly seasonal due to the changing thermal structure in the upper ocean. This paper emphasized a continuing theme of the conference: the real usefulness but frustrating limitations of remote sensing as an oceanographic tool.

Papers by C.M. Gordon and J. Witting (Naval Research Laboratory [NRL], Washington, DC) considered hydrodynamic mechanisms responsible for the surface expression of bathymetry as viewed by SAR. For example, a combination of *in situ* current measurements and kinematic theory indicated that a sand ridge on Nantucket Shoals was due to wave blocking by adverse currents. J. Witting has produced a numerical computer model that reproduces many aspects of the wave-current interaction involved.

J. Venn (City of London Polytechnic) discussed SAR-seabed coincidences in the surface wave field of the English Channel. The clarity of the correspondence of bathymetric features and surface SAR expression make the Seasat images of the channel the most detailed available. Venn finds that the optical density of the SAR imagery can be related to the differential surface velocity of the currents. The ever-present problem of calibrating satellite measurements with sea truth was explored by A. Lygre (Continental Shelf Institute, Norway) with respect to comparison of GEOS satellite altimetric measurements of sea state with waverider buoys. Lygre concluded that algorithms used for correcting meteorological effects are probably inadequate in view of the occasional GEOS indications of 12-m average wave heights recorded near weather fronts.

G. Chabert d'Hieres (Institut de Mecanique, Grenoble) presented an interpretation of remotely sensed, topographically forced eddies, such as the atmospheric or oceanic vortices shed by mountains or islands. He demon-

strated the profound effect of the earth's rotation on such phenomena; both theoretical arguments and laboratory experiments were used to show how the anticyclonic member of a shed vortex pair is unstable when the Rossby number is in the range of 0.5. Generation and remote detection of geophysical vortices was also the subject of Prof. S. Onishi (Science Univ. of Tokyo). The vortices he discussed were produced by a jet of tidal current leaving the Seto Inland Sea through the Naruto Strait. Onishi showed that the theory of turbulent jets and vortex formation in a shear layer adequately described the oceanographic effects in the Naruto Strait. Onishi also presented work by Sugimura, Tanaka, and Hatakeyama (Remote Sensing Technology Center of Japan). They compared historical current measurements and currents in the Sea of Japan calculated from NOAA/AVHRR (advanced very high resolution radiometer) data.

A. Loffet described the remote sensing capabilities of the Belfotor Eurosense Company. Dr. C. Yentsch (Bieglow Laboratory, US) considered multiband color imagery of the ocean as a tool not only for productivity evaluation by chlorophyll measurement, but also as an aid in modeling physical phenomena such as Gulf Stream eddies and their internal structure. Comparisons with *in situ* samples were used to validate the CZCS interpretation. Dr. I. Murali Krishna (National Remote Sensing Agency, India) discussed techniques for optimizing the remote sensing of coastal environmental parameters.

Characterization of the Liguro-Provencal front by remote sensing and field measurements was the subject of the presentation by Dr. J. Hecq (Laboratoire de Biologie Marine, Univ. of Liège). Hecq emphasized the relationship between phytoplankton, silicate concentration, and CZCS imagery of the frontal meanders northwest of Corsica. The work described by Dr. C. Dupouy (Univ. des Sciences et Techniques de Lille) also stressed the relationship of CZCS imagery and chlorophyll production as calibrated by sea measurements. The frontal system she discussed extended between Plymouth, UK, and the coast of France, and was characterized by dinoflagellate blooms in the stratified part of the front.

Dr. M. Crepon (Museum d'Histoire Naturelle, Paris) explored the connection between remote sensing and numerical modeling. He illustrated the topic with infrared imagery of ocean flow near capes and eddies in the Alboran Sea, and related the surface features to predictions of his numerical model. The contribution of Dr. J. Massin (Ministère de l'Environment, France) dealt primarily with the remote sensing of oil spills at sea. Massin discussed various types of airborne and satellite sensors, their role in locating and monitoring oil spills, the special requirements of sensors for enforcing international regulations.

Under the auspices of the NATO committee on Challenges of Modern Society, a round-table discussion on pollution at sea was conducted by Massin on the final day of the colloquium. The discussion centered on the opportunities offered by remote sensing in setting up and operating models to anticipate the movement of maritime pollution. Participants in the round table began planning an Advanced Research Workshop to be held in 1984.

Dr. Selim A. Morcos (UNESCO, Division of Marine Sciences) spoke to the colloquium about the United Nation's interest in encouraging more interaction between marine scientists and the remote sensing community, especially in developing countries. Dr. Morcos is soliciting the advice and counsel of all scientists on (1) training programs for marine scientists in developing countries, and (2) introduction of remote sensing technology into university curricula in marine science. Suggestions may be sent to him at 7, Place de Fontenoy, 75700, Paris.

Complete texts of the conference papers will be published in the Elsevier Oceanographic Series. During the meeting, Nihoul announced that the topic of the Sixteenth Liège Colloquium will be "Coupled Ocean-Atmosphere Models"; it will be held during the first week of May 1984.

J.M. Gordon
NRL, Washington, DC

OPERATIONS RESEARCH

O.R. IN AN ENGINEERING PRODUCTION DEPARTMENT

Operations research (O.R.) began during World War II, when the British government assembled a number of scientists into "operational research" teams to give military executives advice about conducting wartime operations. The teams quickly achieved impressive successes: the problem of incorporating radar into air defense strategies was

solved in the early 1940s, and the work leading to reductions in losses from attacks on allied shipping in the North Atlantic is often cited as a triumph of early O.R. efforts.

After the war, O.R. continued to develop as a discipline concerned with helping decision-makers. In the UK, early development of O.R. took place primarily in large organizations such as industrial companies, banks, hospitals, transport authorities, and various government groups. The nationalized coal industry, the National Coal Board, seems to have served as a training ground for many of the UK's best known operations researchers, and it continues to be a center for extensive, vigorous O.R. activity today. (The industrial development of O.R. in the UK contrasts somewhat with the situation in the US, where the work tended to take place in academic contexts.)

In 1958, the Univ. of Birmingham offered the UK's first master of science (M.Sc.) course in O.R. The 12-month program is still quite vigorous, with about 25 new students enrolling each year. Entry is limited to students having "a good honors degree awarded in a suitable subject," or its equivalent. About 40% of the course work is devoted to O.R. techniques such as mathematical programming, simulation, inventory theory, combinatorics, queuing theory, and decision theory. About 25% of the course work is devoted to statistics, taught by members of the mathematical statistics department of the university. (Some activities of this excellent group were reported in *FSM* 36-12:354-356 [1982].) Other course work is given in areas such as economics, finance, and management. As is common in the UK, about one-third of the M.Sc. course in O.R. is devoted to individual projects; students work for outside companies and government departments, tackling a "real-world" O.R. problem in a working environment.

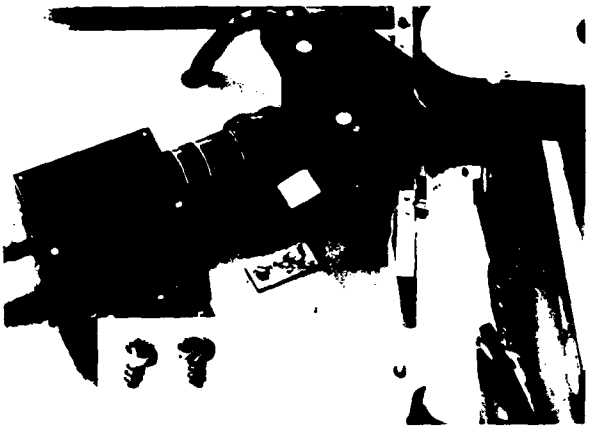
The Birmingham O.R. course is part of the university's Department of Engineering Production. According to Prof. K.B. Haley, head of the department, engineering production is concerned with the planning, organizing, and control functions in manufacturing industries. The fields of interest range from the study of characteristics of individual production processes and individual workers to studies of decision-making at an overall production policy level. The department is concerned with all aspects of production--technical, economic, and human--and particularly with their interactions and coordination. The department's degree in engineering production was given M.Sc. status in 1955; M.Sc. degrees were added for O.R. in 1958, for work design and ergonomics and for quality and reliability in 1964, and for industrial management in 1973. All the courses are of similar duration, and all emphasize at least 3 months of individual student project work.

In addition, the department has the Lucas Institute for Engineering Production, which is a residential short course center. It was founded in the 1950s and, with financial support from the Lucas organization, moved to modern facilities adjoining the university campus. The institute is used exclusively for "residential post experience" short courses, in which individuals such as industrial managers, senior production engineers, and quality engineers can learn about new developments in engineering production. The courses are taught by the Engineering Production Department faculty and well-known researchers from other institutions. The individual courses typically last 5 days, and a variety of course sequences are offered so that a more comprehensive program can be structured to suit individual needs. The institute has living facilities for 40 students and has library and computing resources. The following is a sample of the courses to be offered by the Lucas Institute in the fall of 1983:

- Techniques of Operations Research
- Computers in Production Technology and Management
- Production Planning and Control
- Trends and Advances in Manufacturing Technology
- Advances in Cutting Tool Technology
- Industrial Statistics.

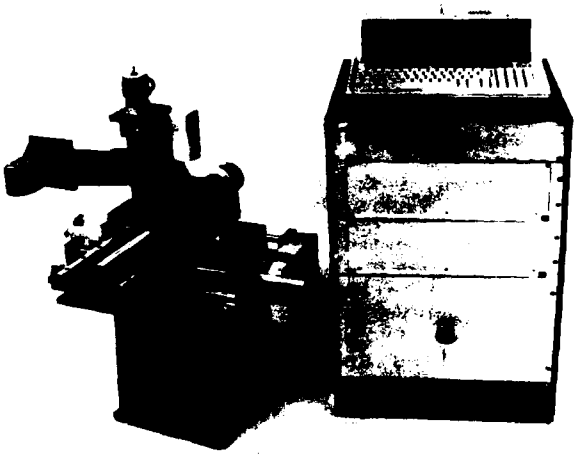
The Engineering Production Department is thus essentially an O.R. department with a heavy industrial engineering content. The department maintains close ties with industry through the Lucas Institute, student practical projects, and consulting arrangements. The ties have motivated the department to become involved with control and production aspects of machines and processes, in addition to work in the more traditional planning, scheduling, and management areas. An example of the control interests of department members is the design of computer control systems for machine tools and development of tool performance measures useful in evaluating such controls. The work involves research in adaptive control using microprocessors, development of industrial robots, and their use in

A MICROPROCESSOR WITH VISUAL RECOGNITION



Here a microprocessor is being used to sort screws. The microprocessor receives signals from a "Line Scan" T.V. camera viewing the edge of screw heads passing through its field of vision. The system discriminates between screws with cracked heads and those with satisfactory heads, rejecting the cracked ones.

GEARCHANGE TESTING BY ROBOT



To test a motor vehicle gearbox thoroughly it is no good asking a top class driver to drive the vehicle all day. The gearbox must be treated roughly as well as gently. This robot can be taught to change gear in the exact manner of any driver — even to letting the clutch in with a jerk!

Figure 1. Recent industrial microprocessor applications developed by the Department of Engineering Production.

applications such as automatic inspection, handling, and quality assessment. During a recent visit to the department, I saw a robot that had been designed and adapted by the Birmingham scientists to test automobile transmissions by simulating shifting maneuvers of various drivers. The robot is being used in the quality assurance program of a major European automobile manufacturer (Figure 1).

Engineering production faculty members are active in a broad range of research projects; the work of Drs. D.J. Sherwin and A.T. Clementson provides typical examples. Sherwin has been working in the quality and reliability area for many years. One of his interests is scheduling inspections for items that fail in an obvious manner. Replacement theory suggests that items with a nonincreasing hazard rate should be left to fail. This ignores the possible value of inspection in warning of impending failure when restorative maintenance is cheaper than failure repair. Sherwin has developed models for determining the best inspection schedules when failures are "self-announcing." The models minimize the long-term cost rate, which involves cost differences between failures and "on condition preventive maintenance" plus inspection costs. Sherwin has also been interested in design and implementation of reliability data bases--especially the cost effectiveness of programs involving collection of detailed failure, maintenance, and cost data. Sherwin argues that by increasing the collection effort slightly above the minimum required for effective financial control, one can obtain a great deal of information that can be used to optimize maintenance schedules.

Clementson is interested in simulation methods. He has recently developed a simulation system called Extended Control and Simulation Language (ECSL). This is a substantial extension and revision of the Control and Simulation Language (CSL) conceived by the O.R. group at the Esso Petroleum Company in the early 1960s as a language to allow easy description of a large tanker fleet simulation then under development at Esso. Together with workers from IBM, the Esso personnel developed a program that translated CSC into Fortran, and this was successfully used for several years. The ECSL software is written in basic Fortran and will, therefore, run on a wide variety of computer systems. The ECSL user does not need to know Fortran, however.

For several years, computer programs for discrete simulations have been written "by hand," using special purpose programming languages such as G.P.S.S., Simscript, and Simula. Use of such languages greatly simplifies the process of building simulations for solving O.R. and management science problems; even so, considerable skill and much time are required to build a simulation in such languages. The ECSL system uses a computer aided design approach to building discrete event simulation

models. ECSL incorporates the "cell structure" simulation concept developed at Lancaster Univ. (UK) and the "visual interactive modeling" methods developed at Warwick Univ. (UK). According to Clementson, the approach differs from that used for simulation in the US; he describes the US methods as an "event approach"; an "activity approach" is used in the UK. Clementson says the activity approach has several advantages--greater simplicity and greater decomposition ability, for example. "It takes about 50% less time for students to learn the activity approach," he says.

Overall, the Engineering Production Department is a vigorous, productive group. It is apparent that working closely with industry is helping to stimulate and guide the department. Such interaction is, after all, at the heart of operations research.

T. A. Atchison

PHYSICS

CONTACT ELECTRIFICATION RESEARCH AT UMIST

Static electricity has been a subject of scientific investigation for centuries, yet some of the fundamental mechanisms remain a mystery. Nor is improved understanding of purely academic interest. Sparking and discharges produced by static electrification represent serious explosion hazards to aircraft, ships, and the natural gas industry. Contact electrification during the manufacture of semiconductor electronic components can lead to damage due to breakdown or the attraction of dust to charged surfaces. On a recent visit to the Univ. of Manchester Institute of Science and Technology (UMIST), I learned of two research efforts concerned with static electrification. The first program, researching contact electrification between metals and insulators, is described in this article. The second, concerned with static charging by collisions of aircraft with ice particles, will be reported in the near future.

Background

Prof. A.C. Rose-Innes, director of the Joint Laboratory of Physics and Electrical Engineering, described his long-term research on contact electrification of insulators by metals. If a metal and insulator are touched together and then separated, an electric charge is usually transferred onto the insulator. Furthermore, if the same spot is repeatedly touched by the metal, more charge is transferred with each contact. Although the amount of charge decreases with subsequent contacts, charge build-up on the insulator can continue for thousands of contacts. Charge accumulation occurs on insulators as different as polyethylene, alkali halides, and diamond. The phenomena of charge transfer and accumulation have been noted by many researchers during the last 15 years, but the mechanisms are just now beginning to be understood.

The most basic problem is why any charge at all should be transferred to the insulator. The work function of metals (typically 4 eV) is considerably less than the energy gap between the full valence band and empty conduction band of ideal insulators (typically 10 eV). As the Fermi level of the metal lies deep within the insulator band gap, and the energy of thermal excitation ($kT \approx 3\times10^{-2}$ eV) is small, no unoccupied states in the insulator should be accessible to electrons in the metal. However, insulators do acquire a contact charge from metals with a typical magnitude of 10^{-11} C/mm^2. This implies that insulators have electron acceptor states (called traps) at or below the Fermi level. The mid-gap states are usually thought to arise because of impurities and defects in the bulk of the insulator and dangling bonds on the surface.

Given the existence of accessible states in the insulator, the second problem is why, after the traps fill on the first contact, additional charge is transferred to the same spot on subsequent contacts. A number of unsatisfactory explanations have been proposed in recent years. One was that charge transfer occurs slowly--i.e, over a time long when compared with the time of contact between metal and insulator. But this has been disproved by observations that the total charge transfers in a much shorter time than the duration of contact. It has been suggested that charge accumulation may be due to deformations of polymers in the region of contact; the deformations bring acceptor sites to the surface or create new ones. However, this mechanism cannot apply to insulators that are harder than the metal. The work of the Joint Laboratory has provided insights into the basic mechanisms for charge transfer and a convincing explanation for one type of charge accumulation.

The Experimental Method

One version of the apparatus used by Rose-Innes and coworkers is shown in Figure 1. With it, a grounded spherical metal contactor can be touched to an insulator specimen in a controlled and reproducible manner. All experiments are carried out in vacuum to prevent discharges and charge leakage to the atmosphere. The contactor is attached to a vertical rod supported by parallel, phosphor-bronze leaf springs that ensure vertical motion and repeated contacts to the same spot on the insulator. The insulator specimen sits on an insulating PTFE (Teflon®) support, which prevents charge leakage to ground. Vertical motion is transmitted to the contactor in vacuum by a bellows and pneumatic system (not shown) which ensures that the impulse and force of the contact are independent of contact duration. The charge transferred to the insulator is measured by swinging a proof plane (not shown) attached to a Keithley 602 electrometer over the insulator between contacts. The illumination system shown in Figure 1 will be discussed below in the context of a specific experiment.

Much of the research requires that several hundred contacts and charge measurements be made over periods of many hours. During such a run, researchers must vary certain parameters --e.g., the time between contacts and contact duration must be varied. A microprocessor-controlled automated system is therefore used so that the experiment can operate unattended.

Mechanisms for Contact Charging

During the past few years, several experimental and theoretical investigations into the basic mechanisms responsible for contact charging have been carried out by the Joint Laboratory. The experimental studies involved specific insulating materials to focus on individual mechanisms. Theoretical work has concentrated on determining the role of electron tunnelling in contact electrification.

To establish that electron acceptor states produced by impurities or defects are responsible for contact charging of insulators, Rose-Innes, G.A. Cottrell, and C. Reed prepared an "ideal" insulator with no electron energy levels in the forbidden energy gap to see if electrification would be suppressed. The ideal insulators were solidified noble gases. These solids are held together by the Van der Waals force since the outer electron (valence) shell is fully occupied. Because the interatomic forces are weak, no bulk crystal defects or surface states were expected to form.

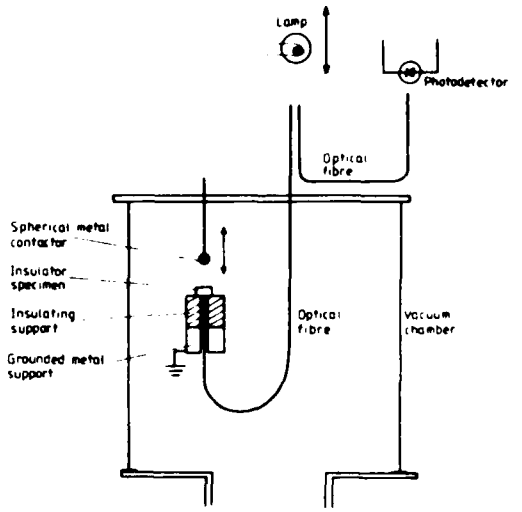


Figure 1. Apparatus for charge transfer measurements.

Plates of solidified Ne, Ar, Kr, and Xe were formed on a copper table cooled in a cryostat to 6°K. Metal balls of Au, Cd, and Al were cooled to the same temperature, and on contact, sank a small distance into the frozen gas. The distance was measured with a micrometer so that the contact area could be determined. The solid rare gas was charged to about $\pm 10^{-13}$ C/mm² on formation so that the contact charge was determined by difference measurements before and after contact.

As predicted for a pure defect-free insulator, no contact charge was detectable down to 5×10^{-14} C/mm²--a level several orders of magnitude below that of common insulators. Following the experiments with the pure insulators, the frozen gas was doped with an electron acceptor by adding Cl_2 gas to argon before condensation. The doped gas acquired a negative contact charge in the range of 10^{-12} to 10^{-10} C/mm² as the concentration of Cl_2 was varied from 0.01 to 1%. The results confirm the role of defects and impurities in contact electrification.

Cottrell performed an experiment to determine the true charge density transferred during contact. The quantity is difficult to measure when hard solids touch, because they do so only at a few points on the microscopically

rough surfaces, the total area of which is much smaller than the apparent area. Theories of charge transfer that predict the charge density cannot be tested unless the true contact area is determined. Cottrell overcame the difficulty by using a soft rubber insulator that can deform elastically around the asperities on the metal surface, thereby providing intimate contact. Optically smooth samples of low-modulus silicone rubber were prepared by liquid casting on optical-quality glass surfaces. Metal flats with a variety of roughness contours were used as contactors.

For single contacts on smooth surfaces, the true charge density transferred to the rubber was measured to be $(15\pm5)\cdot10^{-11}$ C/mm² independent of metal work function and equivalent to about one electron per 10^4 surface atoms. This value is compatible with that predicted in Chowdry and Westgate's model (1974), which assumes midgap states in polymers to be spread over a wide energy range. The charge density remained constant for center-line-average roughnesses up to about 0.3 μm. For rougher surfaces, the charge density decreased monotonically so that loss of intimate contact was inferred.

K.P. Homewood and Rose-Innes performed an experiment to determine the effect of contact time on charge transfer to a polymer. In the past, researchers have reported an enormous range in the charge transfer time (10^{-2} second to days), so the experiment was conducted to clarify the mechanism for the time dependence. A Cd-plated steel ball was brought into contact with a flat PTFE specimen for varying times, and the charges transferred in single contacts were measured. The charge increased by a factor of two as the contact time was varied from 0.3 to 1,000 seconds.

Homewood and Rose-Innes felt that the effect was due to an increasing area of contact with time, so an optical method to measure the change in area was developed. A plano-convex glass lens with a similar curvature to the metal ball was brought into contact with the polymer. Since the reflection coefficient of the glass-polymer interface is less than that of the glass-air interface, the areas of intimate contact viewed through a microscope showed up as dark patches against a light background. The variation of contact area with time was determined from photographs taken at various times during contact. The observed increase in area with time closely followed the variation of contact charge, thereby demonstrating that the time dependence was due to the viscoelastic properties of the polymer rather than any slowness of electron transfer.

J. Lowell has investigated theoretically the role of electron tunnelling in contact ionization. Since the charges in a perfect insulator are immobile, it follows that a trap can participate in electrification only if it is close enough to the surface so that an electron can tunnel to it. In a static situation, Lowell (1979) showed that only insulator states below the metal Fermi level can be populated by this mechanism. However, when the metal and insulator are in relative motion during separation, electrons can populate states above the Fermi level not otherwise energetically accessible. Lowell recently investigated this dynamic case in order to assess the contribution to insulator charging.

Lowell approximated the spatial part of the electron wave function by a linear superposition of states localized in an isolated insulator trap and in the metal, and substituted that form into the time-dependent Schrodinger equation. Four additional approximations allowed him to estimate the probability that the electron would be found in the insulator state following separation from the metal: (1) the energy levels of the two states do not change with time, (2) the wave function in the insulator is roughly constant over the trap volume and negligable outside it, (3) the Bloch (i.e., metal) wave function has a specific spatial dependence, and (4) all electrons in the metal are at the Fermi level. Using a separation velocity of 1 m/s and a 1 eV energy difference between the two states, Lowell found an occupation probability of about 10^{-10}. The value leads to a contact charge density of about 10^{-15} C/mm², much smaller than experimentally observed values. It was concluded that tunnelling is unlikely to contribute significantly to contact electrification.

Charge Accumulation Experiments

In very hard crystalline insulators, deformation on contact cannot be responsible for observed charge accumulation when repeatedly touched by softer metals at the same spot. Recent experiments conducted by Homewood and Rose-Innes have demonstrated that the charge buildup in such cases is due to a slight electrical conductivity. When contact is first made, charge quickly transfers to the insulator and is held close to the region of contact by the attraction

of image charges in the metal. When the metal is withdrawn, the attraction disappears and, by virtue of the slight conductivity, the charge either spreads through the insulator or is partially neutralized by intrinsic charge carriers attracted to the contact region. In either case, some electron-accepting sites will be emptied so that additional charge can be transferred on the next contact.

For the diamond and sapphire insulators studied, photoconductivity was produced by controlled illumination with light of variable intensity; the optical system shown in Figure 1 was used. The vacuum chamber was blackened to avoid extraneous light. The metal contactor used in the experiments was a solid gold sphere about 2 mm in diameter with a contact force of 2 N producing a 0.09-mm² area of contact. The accumulation of contact charge on diamond for different intensities of illumination is shown in Figure 2 for constant contact time and time between contacts held constant. Each curve is labeled by a number proportional to the illumination intensity. The results demonstrate increased accumulation with increased photoconductivity. Two points should be noted: first, with no illumination, charge accumulation is not observed; second, normal room lighting can produce charge accumulation. Figure 3 shows charge accumulation at constant illumination and contact time but with the time between contacts varied. One expects the rate of charge accumulation to increase with the time between contacts when charge is slowly conducted away from the contact region.

Photoconductivity was responsible for charge buildup in diamond and sapphire but not in polymers, according to experiments with polyethylene (PE) and PTFE. The rate of charge accumulation in polymer does not vary greatly with the time between contacts, indicating that volume conduction is insignificant. Other experiments demonstrate that charge spreading by surface conduction in polymers is also unimportant. A line of charge was deposited on PTFE and PE, and surface spreading was measured as a function of time with an electrostatic probe. No spreading was observed after 1 week. Further experiments are clearly needed to examine alternative mechanisms of charge accumulation in polymers.

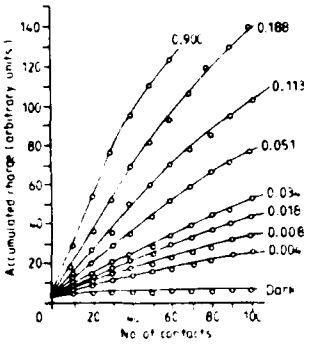


Figure 2. Charge accumulation versus number of contacts for different intensities of illumination.

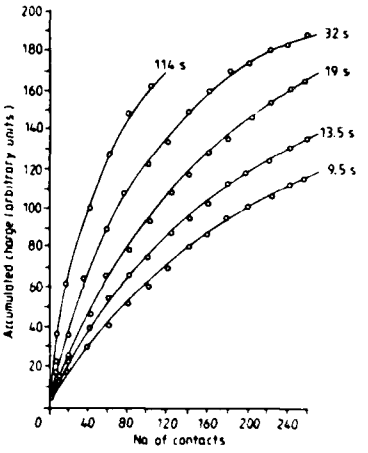


Figure 3. Charge accumulation versus number of contacts for various times between contacts.

Concluding Remarks

The Joint Laboratory of Physics and Electrical Engineering has provided greatly improved understanding of the mechanisms responsible for charge transfer and accumulation on insulators contacted by metals. Experiments and theory have eliminated several incorrect mechanisms. By carefully measuring the true area of contact, the group has determined the charge transferred so that other theories can be tested. Using frozen noble gases as ideal insulators, the group has proven the importance of mid-gap states produced by defects and impurities in real insulators. They have shown that the observed time-dependence of charge transfer to polymers is not due to slowness of electron transfer but to deformation of the contacted surface. In hard crystalline insulators, they have demonstrated that charge accumulation from repeated contact is due to photoconductivity

produced by normal room lighting. This result may be important to semiconductor processors for whom controlled lighting may provide a means of reducing the detrimental effects of static charging during manufacture. However, additional research is required to uncover charge accumulation mechanisms in polymers.

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Lowell, J., *Journal of Physics*, D12 (1979), 1541.

D. Mosher

NAVY-RELEVANT RESEARCH AT THE UNIV. OF LIVERPOOL

The Mechanical Engineering Department at the Univ. of Liverpool conducts broad-based research in hydrodynamics, aerodynamics, structural mechanics, and dynamics in four divisions: Thermodynamics, Fluid Mechanics, Electrohydrodynamics, and Applied Mechanics. Several research efforts in the divisions of immediate interest to the US Navy are described in this article.

Hydrodynamic Test Facility

The high-speed water flume at the Univ. of Liverpool was shown to me by Dr. A. Millward, who described it as the best water channel in the world. It is a versatile facility of value in a number of fields, including civil engineering, oceanography, marine engineering, fluid flow instrumentation, and hydrodynamics, and is readily available for use by industry and research establishments. The facility currently receives UK Science and Engineering Research Council (SERC) funding for marine technology studies. The flume has a wide speed range (up to 6.4 m/s) and can be used as an open channel or closed tunnel. In comparison with typical hydrodynamic installations, it is a precision facility with flow qualities comparable to those of a wind tunnel. Precision flow characteristics are provided by a series of tangential jet injection ports that can be programmed to compensate for the velocity defect produced by the flume walls, thereby maintaining a constant velocity profile across the flow. The facility employs a tilting bed, the angle of which can be controlled to provide good flow characteristics at any speed. When tilted against the flow, standing waves can be established at the critical point.

In the open channel arrangement, the water flow can be accurately controlled down to speeds of 0.03 m/s, permitting calibration and development of oceanographic and fluid flow instruments, such as meters for tidal current, direction, and plankton measurements. The open channel is suitable for testing surface piercing struts and other shapes, such as those encountered in the design of off-shore drilling rigs or jetty piles. Because of the high velocity operation, supercritical wave-free flow can be achieved with a flat surface. Thus, scientists can carry out research and development of high speed (up to 40 knot) surface vessels such as hovercraft, hydrofoils, and planing hulls. Recent work has concentrated on the lateral stability of high speed planing hulls; the problem is that shallow v-shaped hulls tend to ride on one side. Figure 1 shows a view of the open channel working section with resistance measurements conducted on such a hull. Hydrodynamics of tankers, sailing yachts, and submersibles used in oceanographic surveys are also investigated. The effects of shallow water can be studied by raising a false floor to the required depth.

A cover can be fitted over all of the working section, allowing the air pressure above the water surface to be reduced to approximately 0.03 atmosphere so that propellers and hydrofoils can be tested at the correct cavitation and Froude number (describing the dynamics of an inviscid, incompressible fluid in gravity). An alternative cover converts the open channel into a closed water tunnel--Reynolds-number equivalent to a wind tunnel of the same size operating at up to 76 m/s or dynamic-pressure equivalent to one operating at 183 m/s.

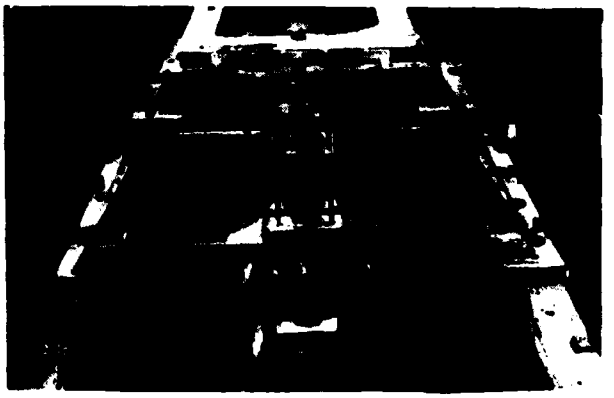

Figure 1. Open channel with planing hull.

The flume is also used to simulate the atmospheric spreading of nonbuoyant plumes, such as natural gas. It is difficult to determine the concentration of the diffusing gas in air. A salt-water, dyed plume takes the place of the dense gas, and the controlled freshwater flow in the flume substitutes for the ambient atmosphere. The dispersion and concentration of the plume are then determined by measuring the local electrical conductivity of the water.

The specifications of the flume are a working section 1.37 m wide and 3.66 m long, a variable depth of 0.153 m to 0.84 m, and a flow velocity range of 0.03 m/s to 6.4 m/s. The flow velocity is uniform across both the width and the length of the working section, and the water surface is free from waves over the full speed range. Ancillary equipment includes two three-component force balances, a one-component force balance, speed measuring instruments, and a variety of photographic and flow visualization instruments.

Turbulent Flow Across Rough Surfaces

A.K. Lewkowicz and F.K. Lim are studying the influence of roughness topography on turbulence as a means of determining the degradation of a ship's hull performance due to corrosion. They have developed a novel experimental method involving taking a plaster cast of a section of actual hull, transferring the cast to rubber that can be folded into a cylinder, and then taking a resin cast for the interior wall of a pipe. By transferring the hull's surface topography to a pipe whose smooth-walled properties are well known, the wall resistance produced by turbulent flow over the rough surface can be conveniently determined. The friction produced by various random distributions of roughness heights, wavelengths, and skewnesses can then be measured to determine the optimum schedule for dry docking.

One investigation involved fully developed turbulent pipe flow with four internal roughness contours: (1) a sinusoid of 0.75-mm amplitude and 5-mm wavelength, (2) an irregular sand grain roughness of 0.9-mm average height and 1-mm average wavelength, (3) a superposition of contours 1 and 2, and (4) a smooth surface for reference and calibration. All tests were carried out in a pipe of 50-mm internal diameter at a pipe Reynold's number of $6 \cdot 10^4$. The mean flow properties and the turbulence parameters were measured.

The pipe friction factor (shear stress/average flow kinetic energy density) and roughness function (downward velocity shift) were plotted as a function of roughness Reynold's number for the four contours. The pipe friction data (Figure 2) show that the long wavelength sinusoidal roughness (RPW) causes a larger increase in friction than the short wavelength sand grain roughness (RPS). The combined effects of the two (RPWS) are only marginally different from the sinusoidal roughness alone. Lim and Lewkowicz believe that the effect occurs because the drag produced by the large scale eddy formation behind the sinusoidal excrescences is not disturbed by the smaller superimposed sand grain excrescences.

The variation across the pipe of turbulent kinetic energy, and its rates of production, dissipation, and diffusion were plotted with three velocity normalizations: the wall friction velocity (shear stress/fluid density), the pipe centerline velocity, and the pipe average velocity. The quantities for the four roughness contours collapsed to a single curve when the data were normalized to the wall friction velocity. The result indicates that the turbulence and wall resistance depend on the wall roughness topography rather than the pipe geometry--an important observation for applicability to ship's hulls because it indicates that velocity gradients near the wall are the same as might be encountered in planar geometry.

Pipe experiments are compared with on-line processing of boundary layer measurements on hulls of Royal Navy ships at sea, with boundary layer calculations and with numerical experiments in which the effect of roughness is included in the boundary conditions at the wall. Other computer calculations involve flow in turbulent boundary layers around larger obstacles situated on top of the roughness contour to simulate in three dimensions the effects of barnacles on the flow characteristics.

Electrohydrodynamics

The Electrohydrodynamics Division, led by Dr. J.L. Sproston, researches the development of clutches and speed control devices using electroviscous media (see ESN 37-2:73-75 [1983]) and studies the flow of convected electrical charges in dielectric liquids. The velocity profiles and flow patterns of the charged particles are determined by laser-Doppler anemometry. The measurements employ two laser beams combined at a precise point within the flow to form a localized interference pattern.[1] As the particles pass through the pattern, they reflect light modulated by the

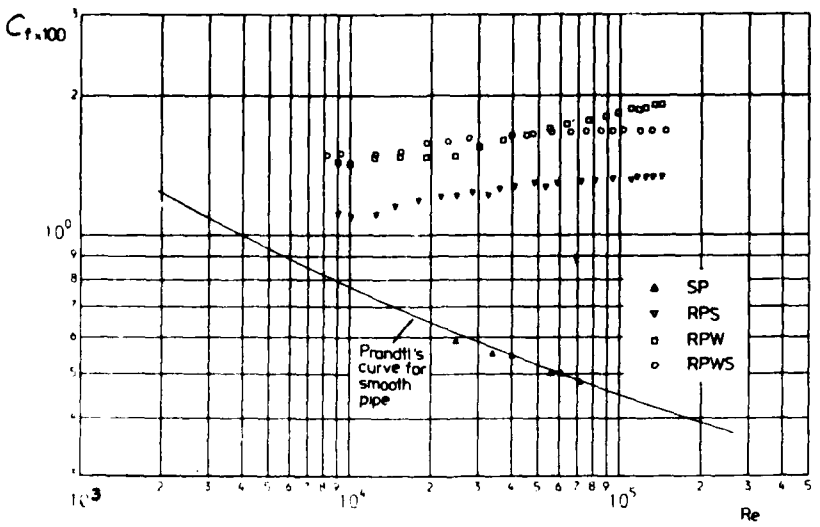

Figure 2. Pipe friction factor

interference. By recording the scattered light, one can determine the density and velocity of the particles embedded in the flow. The size of trace particles is a critical factor for determining the flow field: if they are too large, they will not move with the fluid; if too small, they will be subject to Brownian motion.

Static electrification by fluid flow is investigated because of the role played as an ignition hazard of volatile substances. Convection of dusty gas in plastic pipes can produce large charge buildup by a process similar to that encountered in Van der Graaf generators. The problem is particularly vexing to natural gas producers and suppliers. Grounded metal structures imbedded in the pipes to short out charge accumulation can often aggravate the problem by becoming centers for sparking due to the enhanced electric field at metal edges.

The causes of many ignition hazards are not so easily understood (for example, the explosion of well-grounded, metal supertankers during washing out with salt water). One potential onboard ship hazard thought to be particularly important is the use of CO_2 inerting systems for fire control. The plastic horns commonly used in such systems can become electrostatically charged by the dry CO_2 flow. If explosive mixtures are in the environment being flooded with the inert gas, the hazard may actually be increased by use of such fire extinguishers.

Wind Tunnel Testing

A long-term program of wind tunnel testing is under way to determine the effects of surface roughness on the boundary layer transition between laminar and turbulent flow. The work was described to me by Prof. J.C. Gibbings, the department chairman. When scaled-down wing or turbine blade models are tested in wind tunnels, surface roughness on the front surface is used to trip turbulence at the same location as would be encountered at full scale. The manner in which the roughness causes the boundary layer to separate from the surface must be investigated experimentally to determine those effects which do not scale simply with size. The point of separation cannot be easily determined theoretically or numerically; therefore, a new experimental probe has been developed. The device is a convectively cooled, hot-wire probe specially designed to measure the flow close to the tested surface. The probe has been calibrated in a known flow so that measurement of velocity profiles close to the surface can be used to determine skin friction in the laminar-viscous region. The measurements are particularly important for assessing the performance and stall condition of high-lift wing structures used on deck-landing aircraft.

Gibbings said that until a few years ago, the department's programs were regularly reviewed by ONRL staff members. Based on the work described above, Navy personnel should renew this practice in the future.

D. Mosher

SPACE PHYSICS

SOLAR PHYSICS AT ST. ANDREWS UNIV.

The sun is of major importance to broad areas of space science and astronomy. The interplanetary medium, many properties of planetary magnetospheres, and cosmic ray propagation are examples of phenomena that depend rather directly on solar emissions. Solar activity can produce disturbances in the geophysical space environment, including ionospheric modifications that may affect communications. In astronomy, the sun remains the only star that can be studied sufficiently quantitatively to identify physical processes and to test theories critically.

In recent years, there have been major discoveries and developments in solar physics. A surprising observational finding was that the solar neutrino flux is only about one-third of the predicted value. Explanation may require a revised model of the solar interior or a fundamental change in the elementary particle theory of the neutrino. Explanation of the recently discovered oscillation modes of the sun will require improved models of solar structure. Nimbus 7 and the Solar Maximum Mission (SMM) have measured the solar radiative flux from space and have found variations of a few tenths of a percent in the solar constant. SMM has also revealed properties of solar flares from observations of x-rays and lower frequency emissions. Theoretical developments relate to the generation of magnetic fields, heating of the solar atmosphere, the origin of the solar wind, and identification of some of the proposed mechanisms that may account for the 2-million-degree temperature of the solar corona.

The impressive feature of the developments in solar physics is that it is becoming ever more apparent that many properties of the sun are common to most stars. The sun is neither unique nor anomalous. Applications of the concepts developed for the sun will apply directly to many areas of astronomy.

Solar physics research at St. Andrews Univ., Scotland, is done by the theoretical group in the Department of Applied Mathematics. The group is led by Dr. Eric R. Priest (reader) and Dr. Bernard Roberts (lecturer) and includes two postdoctoral research fellows, T. Forbes and L. Nocera; three graduate students; and Dr. Joseph Hollweg, a visiting theorist from the Univ. of New Hampshire. Active collaborations are carried on with research groups in France, Germany, and the US.

The tools of the theorist, traditional mathematical analysis and modern computer techniques, are used with deliberate balance by the St. Andrews group. Both Priest and Roberts are highly regarded for the solid analysis that underlies much of their research. The work at St. Andrews is well known, probably in large part because the choice of research problems is strongly influenced by recent observational discoveries.

The solar magnetic field controls or modulates many properties of the complex plasma that makes up the solar atmosphere. The equations of magnetohydrodynamics (MHD) are the primary ones used to describe large-scale solar processes. MHD is a nonlinear theory that couples the magnetic field to plasma properties such as density, pressure, and bulk flow velocity. Under realistic conditions, the full set of MHD equations is too difficult to solve explicitly. The task of the theorist is to determine an adequate reduced set of equations that defines a model and that may be explored at least numerically. The primary difficulties in the MHD approach are physical or numerical instabilities. Physical instabilities may relate to microscopic processes that would be addressed through use of kinetic theory, from which the MHD equations derive. Numerical instabilities that affect accuracy often limit the results attainable with large computer codes.

Priest's research includes the study of solar flares, magnetic reconnection, coronal heating, and prominences. His program includes the collaborative efforts of Forbes and Nocera. Forbes has developed useful numerical simulations of magnetic reconnection in solar flares and magnetospheric substorms. Nocera is a new arrival and has begun work on magnetic heating of the corona. Roberts' research includes the study of intense magnetic flux tubes, sunspots, MHD waves in nonuniform media, and solitons. Hollweg is well known for his research on the solar wind, particularly with regard to the role of Alfven waves in accelerating the flow and in accounting for some of the wind's observed properties.

Priest has addressed a number of questions within the context of MHD theory (1983). Before 1978, the explanation for coronal heating was that acoustic waves generated in the photosphere steepened into shocks with altitude and dissipated at coronal

heights. This explanation was disproved in 1978, however, when the measured acoustic flux was found to be far too small to produce the required heating. Many efforts since then have tried to use an analogous magnetic mechanism, whereby heating would derive from the dissipation of MHD waves propagating upward through a vertically structured or stratified solar atmosphere. Unfortunately, such MHD waves tend to undergo small damping and offer inadequate explanations of coronal heating. A possible mechanism for wave dissipation was found recently by J. Heyvaerts (Observatoire de Meudon, France) and Priest for a magnetic field that is laterally as well as vertically stratified. The lateral inhomogenity permits surface waves that dissipate due to phase mixing with vertical propagation. The dissipation appears to be particularly effective for standing waves, which would apply to much of the corona, where the magnetic field tends to occur in flux tubes tied to the sun.

Quiescent prominences are large vertical sheets of cool, dense plasma that extend into the corona and may persist for months. The coolness and remarkable stability of prominences are the principal properties needing explanation. The photospheric magnetic field changes polarity across the prominence and suggests that a force-free sheared magnetic field configuration exists within the prominence. A thermal instability driven by radiative loss is thought to account for the coolness. The force-free field configuration is a source of free energy that would be available to drive instabilities. A magnetic instability, caused by the prominence extending to great altitudes and by the magnetic shear becoming too large, is the proposed mechanism for the eruption of a prominence.

An enormous amount of energy (up to 3×10^{32} ergs) is released into the solar system during a solar flare. Although the mechanism is not well understood, the flare energy involves an efficient conversion of magnetic field energy into particle kinetic energy and radiation. Flares occur when prominences become active, as evidenced by enhanced Hα and soft x-ray emission, and subsequently erupt. Recent SMM Doppler observations indicated a draining of plasma from the summit of the prominence during the flare. The plasma flow and magnetic field behavior suggest that the process of magnetic reconnection, whereby magnetic field lines detach and then reattach, is basic to the flare event. Shock waves that would be generated during the reconnection process would be able to heat the solar atmosphere to temperatures of 20 million to 50 million degrees, which are characteristically observed during flares.

Forbes and Priest have developed an interesting two-dimensional model and numerical simulation of the reconnection process. In their work, the basic MHD equations are solved analytically close to the reconnection site and at asymptotically large distances. The magnetic Reynolds number and the beta of the plasma (the ratio of magnetic to kinetic pressures) are the free parameters, and the initial configuration has an equilibrium current sheet across which the direction of the magnetic field reverses. In the numerical simulation, the current sheet tears on the time scale of the linear tearing mode, and high speed flows build up as the reconnection process develops nonlinearly. Nodes in the magnetic field occur in pairs, in so-called X-point and O-point topologies. In the nonlinear phase of the process, an extra release of energy occurs in bursts with the creation and annihilation of pairs of X- and O-type neutral points. Applications of the model are being developed under conditions appropriate to solar flares and to the magnetospheric substorm process, which involves the geomagnetic tail.

Recent observations have established the surprising and important result that the solar magnetic field occurs in isolated flux tubes of high intensity (1 to 2 kG) over the complete disk. Roberts has investigated the evolution of such tubes as they expand outward from the photosphere through the solar atmosphere producing characteristic waves and instabilities. Using simplified assumptions to represent photospheric conditions, Roberts and A. Mangeney (Observatoire de Paris, Meudon) have considered the possible formation and propagation of solitons along magnetic flux tubes (1982; also see A&A 36-10:262-270 [1982]). One application of such solitons would be to describe spicules as vertical motions ducted by the intense magnetic flux tubes that emerge from the dense photospheric plasma to coronal altitudes.

In other work, additional phenomena are related to the magnetic structure of the solar atmosphere. In the subsurface convection zone, the magnetic field would inhibit heat transport and perhaps result in cool sunspots. When released suddenly above the surface, stored energy may result in solar flares. New modes of MHD wave propagation are permitted in the inhomogeneous magnetic field expanding into space; I.B. Rae and Roberts (1982) have considered the role

of these modes in heating coronal loops, spicules, and photospheric canopies. Plasma heating would derive from a low frequency resonance effect made possible by the structured magnetic field.

Hollweg has investigated the possible heating and acceleration of solar wind ions by MHD waves. The method required development of the first model of a wave-driven, three-fluid solar wind in the region from 10 solar radii to 1 astronomical unit (AU), the earth's orbital distance. The main conclusions of the model were negative; observed properties of ions in the solar wind at 1 AU could not be explained by reasonable MHD wave spectra.

Development of sound theory on the magnetic behavior of the sun will continue to be the primary objective of the St. Andrews group. Problems addressed will be linked to observational facts as much as possible. Thus, there is considerable interest in the progress of the Solar Maximum Mission and the Solar Optical Telescope; both should provide new observational facts that can be applied to the requirements of and guidelines for theory. Priest's work on magnetic reconnection has led to useful interactions with theorists in the laboratory plasma physics community; these relationships should continue to develop in the future. The St. Andrews group has been visible and effective in promoting solar physics through participation in professional meetings, planning boards, and workshops.

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R.L. Carovillano

STATISTICS

APPLICATIONS OF THE MULTI-ARMED BANDIT

Historically, probability in its formal sense seems to have had its beginning in attempts to analyze games of chance. The efforts of the 17th century mathematicians B. Pascal and P. de Fermat to solve a gambling problem posed by a French nobleman of their time are sometimes cited as the beginning of mathematical probability theory.

Even today, probability texts often illustrate basic theoretical concepts by using examples involving games of chance. The examples are deceptively simple; in fact, the resulting models usually can be applied in important ways. The term "one-armed bandit," of course, refers to slot-machines such as those commonly found in gambling casinos. A classical problem in probability is to determine which of several, say k, slot machines a person should choose to play, assuming he intends to play them one at a time in some sequence. The machines may have different payoff probabilities $(p_1, p_2, \ldots, p_k)$, and the player wishes to maximize "profit" from the plays, where "profit" can be defined in various ways. (In the gambling casinos, it might be defined as the expected number of plays until the player's original stake is exhausted.) As the player gains experience through playing each of the k machines, he might favor those that seem to pay off most often. The problem is to devise a scheme using past experience with each of the machines to indicate which one should be played next. The problem and its variations are called the "k-armed bandit problem."

At first glance, the k-armed bandit might seem a frivolous puzzle, but is has an important application: allocation of treatments in medical trials. Imagine a sequence of patients suffering from a common ailment for which k different types of treatments are available. The doctor wants to specify a rule for allocating a treatment to each patient. The rule should depend, at each stage, only on previously observed successes and failures, and it should minimize (in some sense) the number of instances in which patients do not receive the most favorable treatment. Dr. J. Gittins (Oxford Univ.) has commented that solutions to the problem involve compromises between *exploration* and *exploitation*. If one is interested only in maximizing the probability of success on the next trial, one should choose to play the machine with the highest observed relative frequency of success in past trials. This is what Gittins calls exploitation. Exploration, on the other hand, is the concern with gathering information for subsequent long-term use, which may conflict with the desire to achieve the best possible immediate return. Exploration is most important at the start, although exploitation is also of some use in early trials, particularly when the total number, T, of trials that will be

conducted is specified in advance. As the end of such a limited testing sequence is approached, exploitation becomes the predominant consideration.

Prof. J. Bather (Univ. of Sussex, UK) has long been interested in the allocation of treatments in sequential medical experiments. Robbins (1952) defined a decision rule for the k-armed bandit problem to be asymptotically optimal (a.o.) if, with probability 1, it leads to an experienced relative frequency of successes that converges to the largest success probability as the length, t, of the test sequence goes to infinity. Thus, if p_1, p_2, ..., p_k are the success probabilities for the k treatments, and if R(t) is the number of successes observed in t trials conducted with an a.o. rule, then with probability 1, $R(t)/t \to \max\{p_1, p_2, \ldots, p_k\}$. Such rules are easy to devise; use each treatment infinitely often and the current favorite (the treatment with the highest observed relative frequency of successes) most of the time, at least after some finite time. Robbins described a simple a.o. rule for the two-armed bandit problem, which involved "artificial" sequences of positive integers specifying trials in which a given machine would be used, *regardless of its past successes*. Bather has studied a randomized rule that avoids such advance specifications. Let $\{\lambda(n)\}$ be a sequence of positive numbers converging to zero as $n \to \infty$ and let $\chi_i(t)$; $i = 1, 2, \ldots, k$; $t = 1, 2, \ldots$, be independent and identically distributed random variables which are positive and unbounded. Start with one trial under each treatment; after $t > k$ trials, suppose $r_i(t)$ successes have been observed in $n_i(t)$ trials with treatment i. Bather's rule specifies that the treatment at trial t + 1 is chosen to give the maximum (over i) of the quantities

$$Q_i(t) = r_i(t)/n_i(t) + \lambda[n_i(t)]\,\chi_i(t). \qquad (1)$$

Thus, at each stage the treatment to be used is the current favorite according to an index consisting of the current relative frequency of successes, together with a positive "bias." The bias involves randomization, which tends to favor treatments that have so far been used in relatively few trials. On the other hand, the best treatment is used most of the time, after a large number of trials have been made. Bather has shown that such rules are a.o.

Using diffusion approximations, Bather has investigated the long-term behavior of the randomized allocation procedures. The approach is to set up a normal continuous time version of the multi-armed bandit problem and, using the invariance property of Brownian motion, to draw conclusions about the asymptotic behavior of the randomized procedures in discrete time. With this approach, Bather has investigated minimax rules with respect to a loss function involving the expected successes lost (ESL):

$$L(p_1, \ldots, p_r, t) = t \max\{p_1, \ldots, p_k\} - E(R),$$

where the first term on the right-hand side is the expected number of successes with perfect information and the second is the expected number of successes with the rule being used.

In recent work, Bather has compared the performances of a number of "reasonable" rules that could be used in allocating treatments in medical trials. For example, for the case of k = 2 possible treatments, the following fixed and sequential rules are of interest:

- Rule 1. Allocate each treatment to S patients; decide $p_1 > p_2$ if $R_1 > R_2$ (where R_i is the number of successes with treatment i); decide $p_1 < p_2$ otherwise. This is a "play the favorite" nonsequential rule.
- Rule 2. Consider the patients in pairs, each treatment being allocated to one member of each pair. Continue trials until $|R_1 - R_2|$ gets sufficiently large (say equal to a specified integer D); otherwise terminate when some fixed number U of trials have been conducted. Decide $p_1 > p_2$ if $R_1 > R_2$; otherwise decide $p_1 < p_2$. This is a truncated sequential probability ratio test.
- Rule 3. Use the randomized rule given with equation (1), above, where $\lambda(n) = (4 + \sqrt{n})/15n$. (This value emerged from a large number of comparisons reported in Bather [1981].) Terminate after V trials.

Bather has calculated error probabilities and ESLs for the rules in a variety of circumstances. For example,

Table 1

Values for Sequential Rules

Rule \ δ	Error Probabilities .02	.10	.20	.30	Expected Successes Lost .02	.10	.20	.30
1	.42	.16	.02	.002	1.20	5.50	10	15
2	.41	.16	.02	.002	1.20	4.20	5.00	5.00
3	.41	.16	.02	.001	1.20	3.70	3.90	3.26

assuming a finite bound, T, on the maximum length of the experiment, the error probabilities $\varepsilon(p_1, p_2, T)$ after the experiment are constants depending on the unknown parameters. To compare the three rules, Bather chose parameters so that values of sup $|p_1 - p_2| \cdot \varepsilon(p_1, p_2, T)$ were the same for each. One such set of values is to take S = 50 in rule 1: D = 5 and U = 130 in rule 2; and V = 130 in rule 3. Restricting to values of p_1 and p_2 such that $p_1 + p_2 = 1$ and $\delta = |p_1 - p_2|$, some values of error probabilities $\varepsilon(p_1, p_2, T) = \varepsilon(\delta)$ and ESL after 130 trials are given in Table 1. The values show that the two sequential rules lead to terminal decisions, which are just as reliable as those produced by rule 1, but the maximum risk

$$\sup_{p_1, p_2} \{|p_1 - p_2| \sum_{t=1}^{130} \varepsilon(p_1, p_2, t)\} \quad (2)$$

is much smaller with rules 2 and 3 than with rule 1. The argument in equation (2) is the expected number of successes lost as a result of ignorance about p_1 and p_2.

Even though it is clear that sequential methods can be very advantageous, they have not been widely used in medical trials. The comparison of ESLs indicated that sequential methods can deliver the same error rates as the fixed sample designs and that fewer patients receive the inferior treatments. Bather pointed out that rule 3 produces a more equitable sharing of the risks between volunteers involved in the experiment. "With rule 3," he says, "each individual undertakes a risk commensurate with the state of knowledge at the time his treatment is selected. This is an important consideration."

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D. R. Barr

NEWS & NOTES

CHANGE OF COMMAND AT ONR LONDON

CAPT Marshall A. Howard, USN, is the new Commanding Officer, Office of Naval Research Branch Office, London. In a brief ceremony on 17 June, he relieved CAPT Lewis B. Sykes, USN, who is retiring from the Navy.

CAPT Howard comes to ONR London from ONR Headquarters, where he was Project Manager, Aviation and Aerospace Technology, and the Navy Liaison Officer to NATO's Advisory Group on Aerospace Research and Development. Designated a Naval aviator in 1961, he has been involved in aircraft carrier aviation and was Navigator, USS *Independence*. CAPT Howard holds a bachelor's degree in chemistry and a master's in materials science.

ONR LONDON STAFF CHANGES

In June, we welcomed aboard Dr. R. Dolan, a marine geologist who comes from the Department of Environmental Sciences at the Univ. of Virginia, Charlottesville. Also joining the staff in June was Dr. C. McKinney, a specialist in underwater acoustics from the Applied Research Laboratories of The Univ. of Texas at Austin.

In July, Dr. N.A. Bond, Jr., moved to Tokyo, where he will be liaison scientist for ONR Far East.

SPACE INVADERS AND HEART RATE

Uncertainty can produce "exaggerated" cardiac activity. For example, if an experimental subject knows he must react quickly to avoid an electric shock, but does not know what the time limit is, the cardiac increase observed is well above the energy requirements of the task. If the task is too easy, or so difficult that failure is certain, then the cardiac "over-activity" is much reduced. Punishment or aversive circumstances are not required either; competition for bonuses in an experimental game produces the same exceptional cardiac responses. At least one study (Light, 1981) showed that people who exhibited the cardiac over-reactivity to the game tended to have parents with hypertension; such a result suggests the desirability of exploring individual differences in cardiac reactivity over a fairly long experimental series.

At the Univ. of Birmingham (UK), J.R. Turner, Douglas Carroll, and Hazel Courtney used a computer game similar to "Space Invaders" to produce active stimulus uncertainty. A Pet 2001 microprocessor drove the game and the sound track; the player used two keys under the right hand to control left-right movement; a key under the left hand was the "firing button." The setup used Beckman instrumentation and included the R11A Dynograph for heart rate and the Metabolic Cart for metabolic respiratory parameters.

Automatically recorded data from the Cart were available for respiration rate, tidal volume, oxygen volume consumption, and CO_2 volume production. Average values were printed out for 5-minute epochs and could easily be correlated with Dynograph heart rates. Baseline levels were determined for all parameters. Two task conditions were designed into the experiment and counterbalanced across subjects: in the "active" task, the game was played by the subject, whereas in the "control" or passive condition the subjects watched the game "play itself" automatically, and the subject's key responses had no effect on performance.

Very strong experimental effects on heart rate were noted for the "active" Space Invaders condition. With change scores determined from their own baselines, people could also be identified as either "high" or "low" heart-rate reactors. However, "high" heart-rate subjects were not necessarily high in consuming oxygen or producing carbon dioxide. In addition, the "highs" and "lows" observed during active playing of the game were not the same people who were higher or lower on the baseline and control measurements.

The findings already have two implications for researchers in the area. One is that high heart involvement to an uncertain game situation may produce specific but quite reliable indexes of "over-reactivity"--indexes that are relatively independent of metabolic and respiratory indicators. A second significant result, and one of practical importance, is that the intrinsic interest of the game itself makes the experimental situation much more attractive than the usual laboratory setup. The latter feature should help investigators maintain subject cohorts over extended trials, and to discover whether the over-reactivity can be reduced through simple practice or special training.

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N.A. Bond, Jr.

LASER TREATMENT OF BURNS

According to the *Soviet News Abstract Publication* (22 March 1983), laser methods have been used successfully in Russia for the treatment of burns. A small nitrogen laser unit delivers a beam to the surface of the burn; antisepsis, improved circulation, and more rapid healing are claimed.

Treatment is administered once a day for 30 to 180 seconds. No further technical details on the treatment were published in the abstract. More than 300 persons have been treated at the Scientific Research Institute of First Aid. Larisa Wanova Gerasimova, head of the department of acute heat injuries, was the reporting investigator.

N.A. Bond, Jr.

"OFFICIAL" DRUG ADDICTS IN BRITAIN

There are now nearly 5,000 drug addicts "...known to the Home Office" in the UK. Doctors who prescribe any of 14 drugs (e.g., heroin, morphine, phenazocine, methadone, cocaine) are required to furnish patient particulars to the Home Office. Though the real addict population probably is much larger, the Home Office figures do give some idea of the growth in the British addict cohort. Ten years ago, the Home Office list included only about 1,600 addicts, so that the annual increase over the decade has averaged about 11%.

A recent academic study of the illegal "drug subculture" in London's Piccadilly Circus was reported by the *British Journal of Addiction* in 1982. Between 200 and 300 users and dealers regularly operate in the area. Many of the people are well known to each other; it was possible for the investigators to penetrate the subculture quickly and recognize the "regulars." One surprising result: Piccadilly is a tourist center of London, but so far as could be determined, the drug subculture and its hundreds of deals had absolutely no visible effects on the thousands of tourists who visit Piccadilly every day.

N.A. Bond, Jr.

HERPES VACCINATION TRIAL AT BIRMINGHAM

Infection with Herpes Simplex II often produces painful genital blisters; furthermore, attacks may be recurrent. One hypothesis is that infection is correlated with cervical cancer. In Britain, there are thousands of new cases every year. Popular news stories have even suggested that fear of catching the disease, transmitting it to others, or suffering a recurrence is responsible for a "new celibacy" in some young adults.

An encouraging report from the Univ. of Birmingham (UK) on a vaccination trial will be of interest to many clinicians. The total sample of 220 volunteers was classified into three groups: noninfected sexual partners of people who were known to have experienced at least one herpes attack (100 cases), people suffering a first attack (40 cases), and people who have had numerous recurrences (80 cases). All 220 were vaccinated and were followed up for 6 months. Most impressive was the result with the 100 partners, not one of whom appeared to have caught the disease within 6 months. In the 40 first-attack cases, only six suffered recurrences, a much lower rate than expected. The "frequents" claimed that their attacks were less frequent, and also less severe.

Reportedly, the vaccine is manufactured from Simplex I virus, which is grown in special cells and then has its nucleic acid removed; without the nucleic material, genetic information is so reduced that infection cannot take place. Larger trials are planned; the vaccine will be made at the Centre for Applied Microbiological Research at Portfon Down (UK).

N.A. Bond, Jr.

NEW INHALATION TUBE

Asthmatics often have difficulty treating themselves with aerosols during severe attacks; the problem is coordinating the spray output with inhalation. A simple mouth sprayer from Draco AB, Lund, Sweden, may help many patients. To use the new device, one sprays the drug into a fairly large (750 ml) plastic tube; a one-way valve in the tube reportedly releases the spray so as to reduce impaction and cloud reaction. As there is no intravenous injection or power supply involved, the tube is cheap and easy to use, and it already has survived preliminary clinical trials in European allergy clinics.

N.A. Bond, Jr.

FATIGUE 84

The Second International Conference on Fatigue and Fatigue Thresholds is to be held from 3 through 7 September 1984 at the Univ. of Birmingham, UK. Dr. C.J. Beevers at the university is chairman of the organizing committee. The conference is to cover the influence of the following variables on the fatigue and fatigue threshold characteristics of metals and other materials: environment, stress, frequency, mechanical properties, temperature, stress history, creep, crack closure, mixed modes of loading, surface treatments, microstructure, variable amplitude loading, welded joints, geometrical factors, initiation and growth of short cracks, mechanisms, and models for the prediction of fatigue thresholds and fatigue crack growth rates. Of particular interest are submissions relating to the role of fatigue and fatigue thresholds in the design and operation of gas turbines, transportation systems, power generating plants, and offshore structures. For further information, contact Beevers, Department of Metallurgy and Materials, the Univ. of Birmingham, Birmingham B15 2TT, UK.

Researchers in the area might be interested to know that Beevers, in conjunction with the Lucas Institute for Engineering Production, presented a 3-day residential course on "Crack Length Measurement." The course was held at the Univ. of Birmingham from 1 through 3 June 1983. Besides Beevers and Dr. M.D. Halliday, visiting lecturers were Mr. K.A. Taylor, Department of Mechanical Engineering, University College London; Dr. L.J. Bond, Department of Electronic and Electrical Engineering (DEEE), University College London; and Dr. G.A.D. Briggs, Department of Metallurgy and Science of Materials, Univ. of Oxford. The research activities of Bond and Briggs on the scanning acoustic microscope for crack observations were mentioned in *ESN* 37-3: 105-111 (1983). Bond is involved with ultrasonic wave propagation and scattering computer programs for structural characterizations based on finite difference methods. Prof. E.A. Ash, Head of DEEE, is co-editor with C.R. Hill of *Acoustical Imaging*, Vol 12, Proceedings of the Twelfth International Symposium on Acoustical Imaging (New York: Plenum Publ., 1982).

R.W. Armstrong

BREAKING MOLECULES IN SOLID EXPLOSIVES

Ignition of solid explosives has been a long-standing field of research at the Physics and Chemistry of Solids, Cavendish Laboratory, Univ. of Cambridge. The work was pioneered by Profs. F.P. Bowden, D. Tabor, and colleagues. Recently, J.E. Field, G.M. Swallowe, and S.N. Heavens (1982) described the following main mechanisms for initiation by mechanical impact: adiabatic compression of trapped gas spaces, viscous heating of rapidly extruded material between the impacted surfaces or individual grains, friction between rubbing surfaces, and localized adiabatic shear of material during mechanical failure. The latter mechanism is of current interest to researchers involved with explosives and propellents. As a step in the model consideration of adiabatic heating due to plastic flow, R.W. Armstrong, S.C. Coffey, and W.L. Elban (1982) have attributed the generation of a "hot spot" to thermal dissipation of the interaction energy within bunched-up dislocations at the tip of a pile-up released suddenly from a collapsed obstacle.

An innovative experiment on the subject of initiation has been reported more recently by H.M. Hauser, J.E. Field, and V. Krishna Mohan (1983). Molecular fragments from the fracture-induced decomposition of pentaerythritol tetranitrate (PETN) have been detected by time-of-flight mass spectrometry measurements. PETN is a relatively brittle high explosive. When fractured by an explosively driven chisel, decomposition peaks of mass-to-charge ratios (m/e) of 15, 18, 28, 29, 30, 44, and 60 were found--presumably for CH_3, H_2O, CO, HCO, NO, CO_2 or N_2O, and CH_2ONO, respectively. Typical spectra are shown in Figure 1, which also provides information on the time scale for development of the various peaks.

Significantly different spectra were observed by fracturing PETN at a slower loading rate; principal peaks at m/e of 60 and 76 (for CH_2ONO_2) were obtained; other peaks were only minor. Relatively smooth fracture surfaces were observed for the slower fracturing process, particularly matching the observation of the m/e peak at 76 proposed for CH_2ONO_2. The species is normally produced during the thermal decomposition of PETN by the breakage of one of the four nitrate-ester linkages.

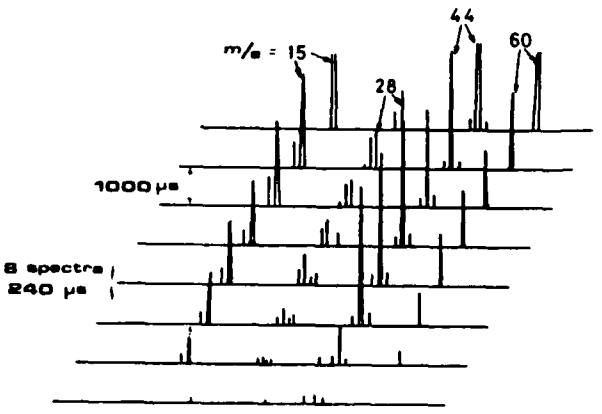

Figure 1. Mass spectra taken during energetic fracture after a time delay of 350 μs.

The fracturing experiment is interpreted as showing that different decomposition pathways are produced depending on the energy associated with the cracking processes. Surplus energy appears to allow breakage of the stronger carbon-carbon bond to produce CH_2ONO. Similar differences in reaction pathways are found in the thermal decomposition and explosion of lead azotetrazole, $N_4C\text{-}CN_4\cdot Pb(OH)_2$.

With the experiments, Cavendish Laboratory is clearly providing additional important information that will eventually help explain ignition mechanisms. The latest work was supported by grants from the UK Science and Engineering Research Council and the Procurement Executive, Ministry of Defence.

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Hauser, H.M., J.E. Field, and V. Krishna Mohan, "Fracture-Induced Decomposition of a Brittle High Explosive: Pentaerythritol Tetranitrate," *Chemical Physics Letters* (1983), in press.

R.W. Armstrong

REMOTE SENSING DEGREE

A 1-year M.Sc. degree course in remote sensing was recently announced by the UK's Science and Engineering Research Council (SERC). Jointly funded by the SERC and the National Environment Research Council (UK), the course will be organized by University College London and Imperial College of Science and Technology, London. It is designed to include the scientific principles and applications of remote sensing.

According to the SERC announcement, students will be taught the basic principles of image processing, data handling techniques, the physics of sensors and space platform design, and the fundamental principles of electromagnetic radiation and its behavior in the atmosphere. The course will also cover applications of remote sensing data, such as location of mineral resources, environmental monitoring, hydrology, crop prediction, oceanography, and meteorology. It is expected to begin this fall.

D. E. Barr

ONRL COSPONSORED CONFERENCES

ONR London can nominate two registration-free participants in the conferences it supports. Readers who are interested in such participation should contact the Chief Scientist, ONR London, as soon as possible.

Workshop on Statistical Quality Control, Canterbury, UK, 4-6 July 1983.

NATO ASI on Physics of Submicron Semiconductor Devices, Pisa, Italy, 10-23 July 1983.

Seventh International Conference on Vacuum Ultraviolet Radiation Physics, Jerusalem, Israel, 8-12 August 1983,

8th European Symposium on Fluorine Chemistry (ESFC-8), Jerusalem, Israel, 21-26 August 1983.

Sixth International Conference on Erosion by Liquid and Solid Impact (ELSI VI), Cambridge, UK, 4-8 September 1983.

International Conference on Electronic Properties of Two-Dimensional Systems, Oxford, UK, 5-9 September 1983.

1983 International Conference on Fourier Transform Spectroscopy, Durham, UK, 5-9 September 1983.

Second International Valencia Meeting on Bayesian Statistics, Valencia, Spain, 6-10 September 1983.

Microcircuit Engineering 83 Conference, Cambridge, UK, 26-29 September 1983.

16th European Conference on Lase. Interaction With Matter, Imperial College, London, UK, 26-30 September 1983.

EUROPEAN VISITORS TO THE US SUPPORTED BY ONR LONDON

Visitor	Affiliation	Organization to be Visited
Prof. H.C.A. Dale	Ergonomics Research Group Univ. of Hull 26 Newland Park Hull HU5 2DW	Navy Personnel Research & Development Center, San Diego, CA (27-29 June 1983) Aviation Psychology Lab Ohio State Univ. (4-6 July 1983) Wright-Patterson AFB (4-6 July 1983)
Dr. V.K. Mohan	Department of Physics Cavendish Laboratory Madingly Road Cambridge, CB3 OHE	NSWC, White Oak, MD (30 June - 1 July 1983) ARRADCOM, NJ (7-8 July 1983) U.S. Bureau of Mines Pittsburgh, PA (11-12 July 1983) Los Alamos National Lab Santa Fe, NM (18-21 July 1983) Lawrence Livermore Lab, CA (25-26 July 1983)
Dr. G.D.W. Smith	Univ. of Oxford Department of Metallurgy and Science of Materials Parks Road Oxford OX1 3PH	Naval Research Lab Washington, DC (8 August 1983) MIT, Cambridge, MA (18-26 July 1983)

ONRL REPORTS

To request reports, check the boxes on the self-addressed mailer and return it to ONRL.

C-5-83: *The 18th International Symposium on Applied Military Psychology*, by N.A. Bond, Jr. The symposium concentrated on five themes: stress research and management, administrative and management issues, women in the armed forces, information processing, and selection and prediction.

C-6-83: *The 29th International Field Emission Symposium*, by T.E. Feuchtwang. The 29th Annual Field Emission Symposium was held at the Chalmers Technical Univ. in Göteborg, Sweden, from 9 through 13 August 1982. The topics exciting most interest were liquid metal ion sources and pulsed laser atom-probes. There were considerably fewer papers on electron emission than on ion emission. About half the papers were concerned with specific applications.

C-7-83: *NATO/AGARD Symposium on Software for Avionics*, by D. Weiss. The symposium was concerned with requirements, design, development, verification, and validation of avionics software. A few papers concerned research results and future technology, but most dealt with the practical aspects of software development.

C-8-83: *Ultraviolet and X-ray Spectroscopy of Astrophysical and Laboratory Plasmas*, by R.D. Bleach. The meeting concentrated on four categories of studies: solar; laboratory; stellar, interstellar, and galactic; and theoretical.

C-9-83: *The 1982 International Congress of Photographic Science*, by L. Slifkin. Conference papers treated topics ranging from fundamental solid state physics of the silver halides to problems in the production of photographic products. This report describes primarily contributions closer to the chemistry and physics of crystalline solids.

R-5-83: *Decision Aiding in Europe: Assessment Report*, by N.A. Bond, Jr. Europeans are doing important work in medium-size decision aiding packages--unburdening, diagnostic, and structuring systems. In large military command and control configurations, European technology is appreciably behind the American state of the art.

R-6-83: *Fiber Composite Materials Research in the UK*, by T.-W. Chou. This report examines the status of basic research on fiber composites in the UK. The information is based on interviews at 15 universities, governmental laboratories, and industrial companies.

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